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JUN 77 A J EISENBERGER, P KASZERMAN DAAB07-76-C-0032

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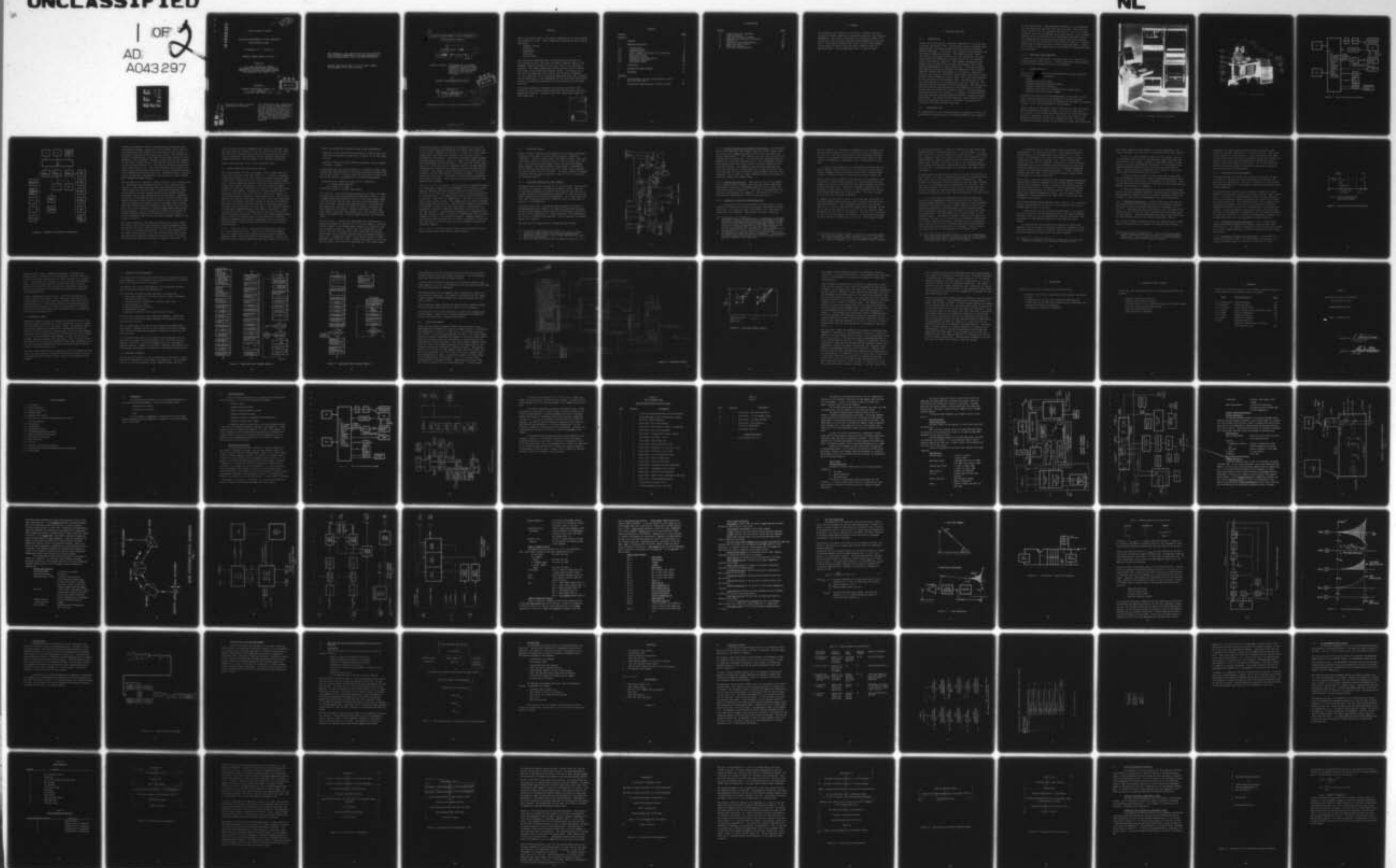

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AD A043297

FOURTH QUARTERLY REPORT

PRODUCTION MEASUREMENT OF FUZE COMPONENTS UNDER DYNAMIC STRESS

11 FEBRUARY 1977 - 10 MAY 1977

CONTRACT NUMBER DAAB07-76-C-0032

PLACED BY

U.S. ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
COMMUNICATION SYSTEMS PROCUREMENT BRANCH
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PRODUCTION MEASUREMENT OF FUZE COMPONENTS UNDER DYNAMIC STRESS.

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FOURTH QUARTERLY REPORT. no. 4,

11 FEBRUARY 1977 — 10 MAY 1977,

OBJECT OF STUDY: DEVELOPMENT OF A COMPUTER CONTROLLED AUTOMATIC TESTER, CAPABLE OF TESTING AND TRIMMING THICK FILM ADJUSTMENT *CIRCUITS AT THE RATE OF* 3,000/HOUR

15

CONTRACT NUMBER DAAB07-76-C-0032

PREPARED BY

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ABSTRACT

During the fourth quarter, the major components of the test station were delivered to LEC. These components consisted of the following subsystems:

- . Computer control.
- . Stimulus.
- . Measurement.
- . Interface.
- . Laser Trimmer.

The first four subsystems were re-integrated and checked as a total system by LEC. The tests included a complete check of the software operating system, as well as a test of all peripheral hardware. The laser trimmer was tested manually and on a stand-alone basis using simulated computer inputs. The simulation of the real-time amplifier test program was 90 percent completed. All the components for the prototype amplifiers have been received. Initial deliveries of the components for the prototype oscillators and for the production amplifiers and oscillators also have been received.

The system approach to generating an accurate oscillator test signal and test system has been completed and the major long lead components selected. Purchase orders for these major items are being generated.

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1. PURPOSE

The purpose of this program is to develop a dynamic test and correction system, capable of high-speed operation, for electronic assemblies. The circuits selected for verification under this contract are the oscillator and amplifier assemblies of the M732 Fuze. The contract requires that 3,000 units of each assembly be delivered, of which 2,900 have been trimmed to meet the specifications. The required test rate is 3,000 an hour.

2. NARRATIVE AND DATA

2.1 INTRODUCTION

During the fourth quarter, the major components of the test station were delivered to LEC. The computer control, stimulus, measurement, and interface systems were first tested by Hewlett-Packard personnel. These tests were repeated by LEC personnel as the final acceptance procedure. The computer control tests consisted of individual checks on all the elements of the operating system and associated programs such as the file manager, editor, and program compilers. The hardware peripherals were tested using Fortran driver programs and checking with actual hardware measurements at each output point. The laser trimmer was checked by Quantrad personnel and repeated by LEC personnel. Computer command were simulated by a test device. Beam positioning, laser optics, interface, laser status, and laser cutting ability were successfully tested. Again, the tests were repeated by LEC personnel as an acceptance test. The simulation of the real-time amplifier test program was 90 percent completed. The main-line routine has been written and debugged. The subroutines have been written and debugged with the exception of the DFT routine and the convolution integral routine. Detailed programming specifications were written. In addition to describing the real-time program, the specifications include a complete system description. The design of the modulation device has been completed and component selection is underway. The majority of prototype fuze parts has been received.

2.2 REDESIGNED FUZE

All components for the prototype amplifier assembly have been received and the manufacture of prototype assemblies will commence

in the next quarter. Approximately 90 percent of the components for the production amplifier have been received. Only the trimmable resistor and the integrated circuit (IC) have not yet been received, with the IC expected in the next quarter. The trimmable resistor will be ordered after the prototypes have been tested. All components for the prototype oscillator have been received, except for the printed circuit board and chip capacitor. Limited quantities of these units are presently being evaluated. Eighty-five percent of the components for the production oscillators have been received.

2.2.1 Oscillator Chip Capacitor

A number of chip capacitors of the new binary ratio design were screen printed, fired and cut. Several pieces had leads attached and electrical characterization is in progress.

2.3 SYSTEM CHECKOUT

The test station system is a third-generation system consisting of the following major elements:

- Comp[illegible]
- Computer-generated stimuli.
- Computer-controlled sampling system.
- Computer-controlled interface.
- Computer calculation of parameters from sampled data.
- Computer-controlled laser trimmer.

By adding the laser to the third-generation test system, a real-time, computer-controlled trim capability has been realized. During the last quarter the major hardware was delivered and tested. Figures 1 and 2 are photographs of the equipment.

Figure 3 shows the conceptual system and figure 4 shows the actual system except for the laser trimmer. During the third quarter, this portion of the system was checked out at the Hewlett-Packard factory in Cupertino, California. During the last quarter, the system was delivered and the tests repeated at LEC. The tests consisted of separate checks on the operating system and integrated

Figure 1. Computer and TTY Equipment

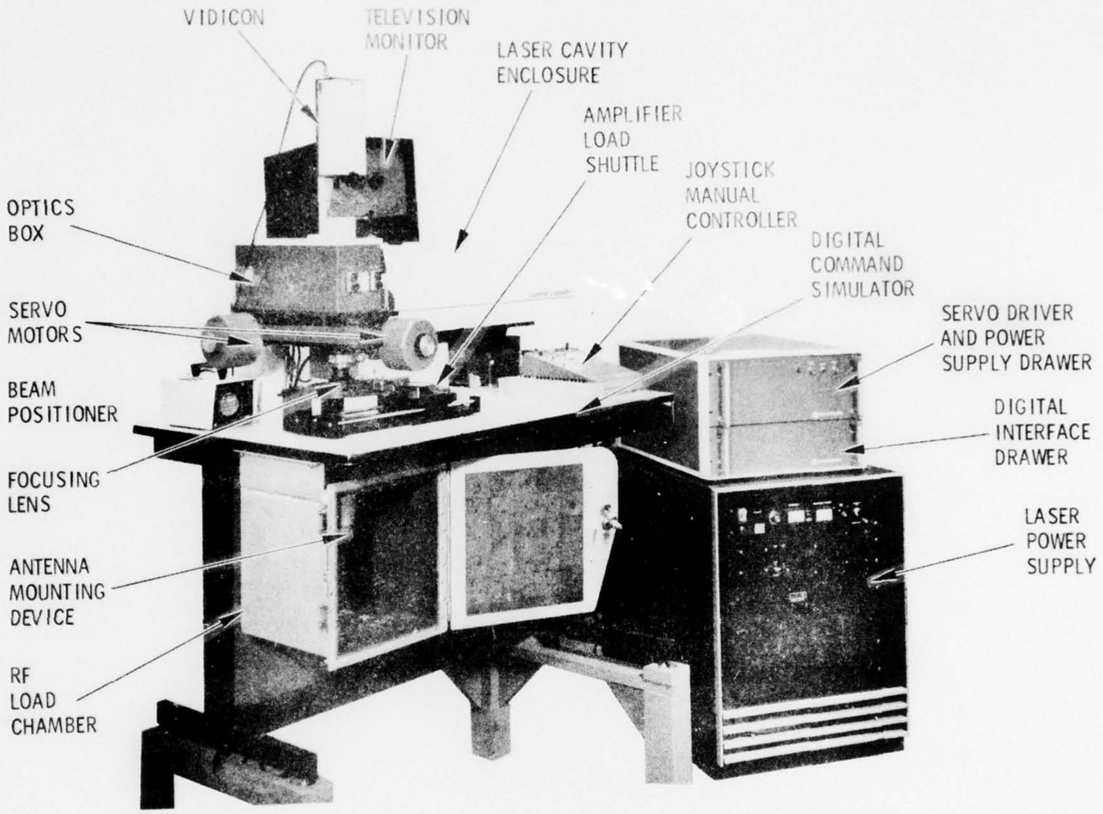

Figure 2. Laser Equipment

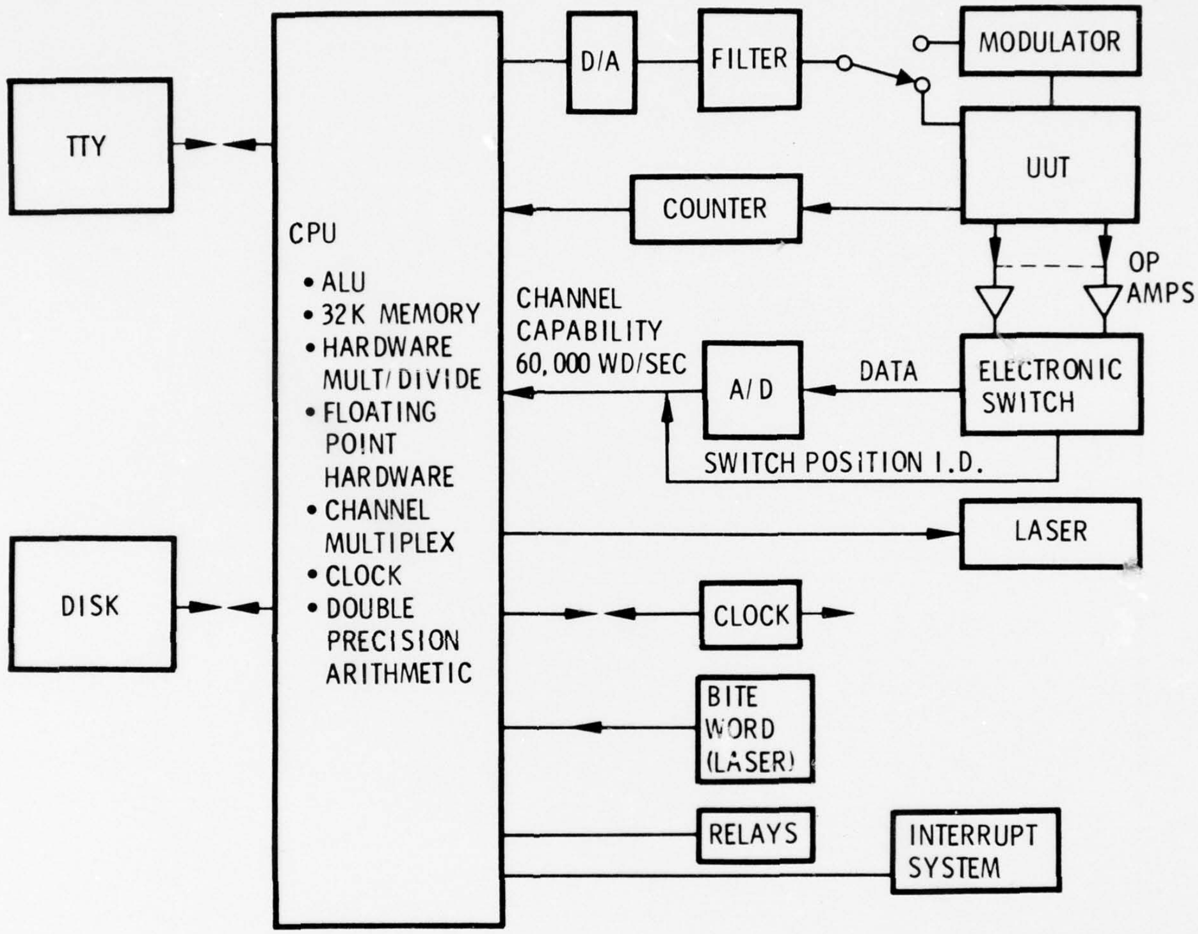

Figure 3. Test and Correction System

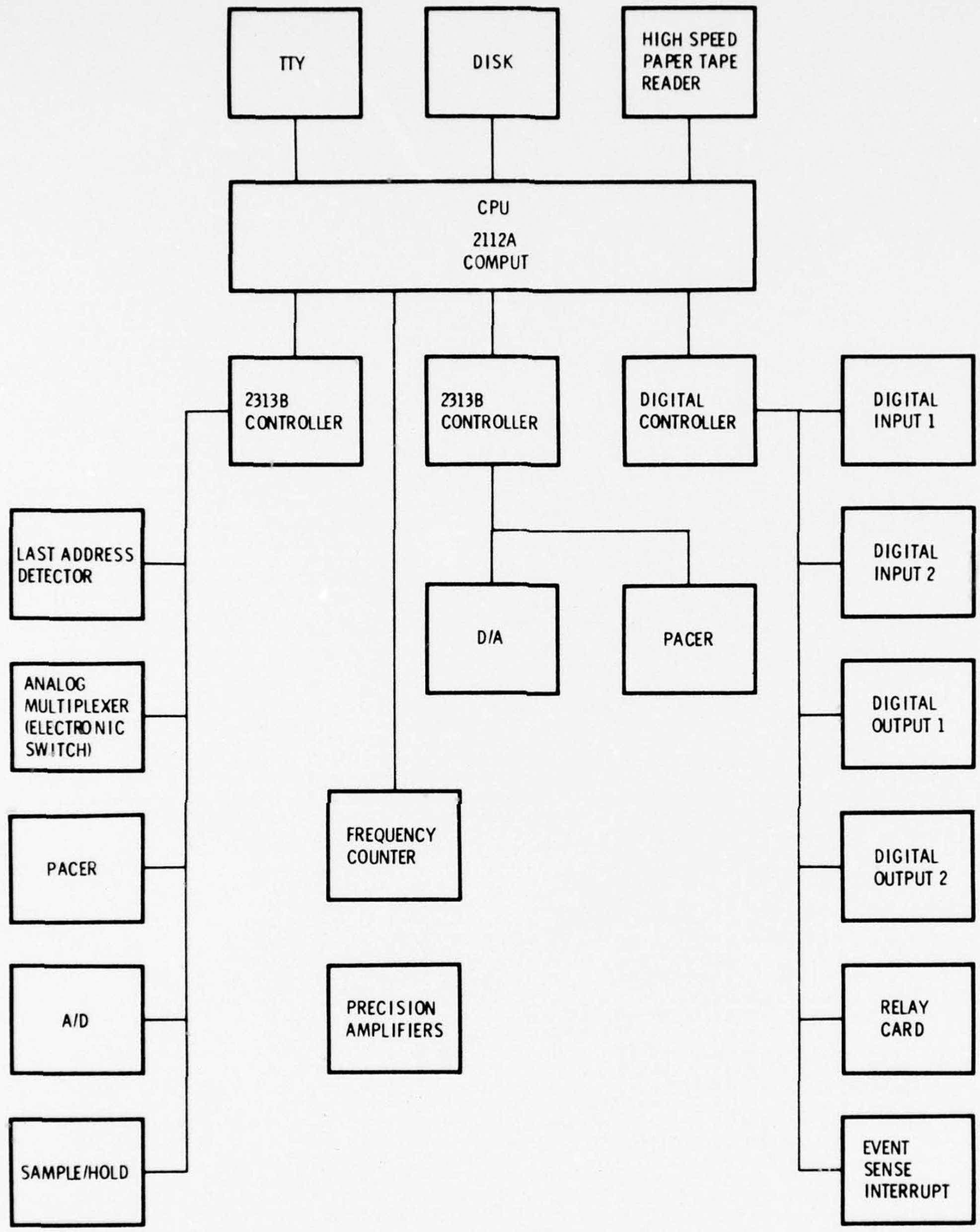

Figure 4. Computer and Computer Peripherals

software-to-hardware tests for each peripheral device and card. The operating system, consisting of the software, disk, TTY, and high-speed paper tape reader, was exercised by first reading in diagnostic programs from the paper tape reader. The TTY was automatically checked since it was used as the system console to enter commands to the diagnostic programs, and was used by the computer as the output printer device. The disk and its setup was checked by writing and reading to it. The specific elements of the operating control system (i.e., real-time executive, file manager, and editor) were exercised by being called, and by having the operator enter commands controlled by each one. Programs written in Fortran, Algol, and Assembly language were compiled and run; these results were compared to known results.

Each peripheral was checked by either writing to it or reading from it. Each pacer was checked by setting it for a specific rate, reading a fixed number of words, and then checking the elapsed time by using the internal clock. The analog multiplexer (electronic switch) and last address detector were checked together by putting known fixed voltages on the switch points, commanding the switch to read through several cycles, and then checking the numbers against a table of known correct values. While the high-level multiplexer was checked, the a/d and sample-hold voltages were also checked since the voltages on the switch had to be sampled, held, and converted to a digital number before being read by the computer. The d/a voltage was checked by outputting two different digital values from the computer and then checking (with a voltmeter) that the correct analog voltages appear at the output of the d/a.

The cards connected to the digital controller were also tested. The digital input cards were tested by applying alternate zeros and ones to the input, reading from the card, and then comparing the card to a stored correct value. The test was repeated with alternate ones and zeros. The digital output cards were tested by successively outputting alternate zeros and ones, alternate ones and zeros, and then checking the output of the cards. The

relay card was tested by commanding each relay to open and close, and then physically checking to be sure that this did take place. The event-sense interrupt was tested by energizing each of the 12 bits in succession, and checking that the computer program was indeed interrupted, and had jumped to an interrupt subroutine.

These tests were made as the final acceptance tests.

2.4 LASER SYSTEM INSTALLATION AND CHECKOUT

The Quantrad model 1021 YAG programmable laser trimmer was delivered and installed at LEC (see figure 2). A system of constant burning and flashing lights was installed outside the closed laboratory room to indicate the laser status to anyone seeking admission. Safety goggles and warning signs were also acquired in conformity with safety requirements. Visits were made by vendor personnel to check out and adjust the optical and electronics components of the trimmer. Essentially, the same results were obtained as reported in the last Quarterly Report with respect to the checkout/buyoff conducted at the vendor's plant. The RF Load Chamber was mounted to the table, and fiber optic light pipes were built into the antenna positioner holder to provide illumination. The digital interface simulator was used to accurately position the laser beam and several cuts were made in the capacitor pattern at the actual trimming distance to be used in production. Laser cuts were also made in a resistor pattern atop the load shuttle, after refocussing the optics. The long focal length trimming under digital control was demonstrated to the Contracting Officer's Technical Representative during a subsequent visit to the plant. The following is a more detailed description of the tests that were performed:

Laser. - Place the laser in operation, as specified in Section 2.3 of the operating manual. Remove the light shield between the laser output mirror and the optics box, and mount Coherent Radiation Model 205 detector head in the beam path. Connect the detector head to Coherent Radiation Power Meter Model 201, turn on

laser, and perform the following output power measurements:

Q-switch rf off (safety shutter held open to defeat the interlock, and no aperture in the laser) 30 watts (at 21 amps lamp current)

Q-switch as above but with .060-inch aperture 4 watts minimum (10 watts - actual)

To determine that the latter condition is indeed the TEM_{00} mode, observe the defocused beam at the output objective position with an infrared viewer. The spot should be round with a single maximum in the center, and perform the following measurements:

Q-switch rf on, repetition rate set at 5 kilohertz:

2.5 watts output minimum

actual { 3.0 watts at 15 amps
6.5 watts at 20 amps lamp current

Laser Optics. - Set up laser-trim parameters to obtain the smallest spot size, using the aperture and spot-size controls. Trim a sample thick-film substrate using a 2-inch focal length objective, and verify that the spot size can be varied between .001 and .005 inches. Elevate the substrate with a .005-inch shim, and verify that the spot size does not change, confirming the field depth of .010 inches. Install relay lens in table top, mount sample thick-film gold sample at 6.5-inch distance below table, and perform trim. Elevate substrate with .060 shim and repeat.

Beam Positioner. - Connect the beam positioner and place it in operation according to Section 2.4 of the 1021 manual. With the control console in the manual mode, operate the joystick to the four extremes of motion. Verify that the system stops at the limits, and that the limits are 2.000 inches apart by making scribe marks on an anodized aluminum plate and measuring with a steel rule. Command the system to the center (X=2048, Y=2048), and make a mark with the laser. Modify the command to X-1024 and then to X3072, and verify that the marks are 1.000 inches apart.

Verify slew speed by connecting an oscilloscope to TP 1 on the X axis control board and observing the voltage under manual joystick control. Measure the time for a traverse of 1 inch (eight revolutions) and divide the voltage at TP 1 by this time to calibrate the tachometer. Using this calibration number measure the peak voltage during a slew of at least .250 inches (two turn discs placement from the end point). The slew rate should calculate to 4 inches per second. Repeated slews can be performed by commanding the system to the center and turning the mode switch to manual. The system is then displaced from the center by the joystick, and the mode switch is returned to remote. The positioner will then slew to the center, and the rate is measured by the tachometer signal. Trim rates are similarly checked by commanding the trim mode.

Interface and Digital Control. - The interface is checked by means of a simulator, supplying 25 milliamperes to the inputs on which ones are desired, and leaving open inputs for which zeros are desired. The strobe line is supplied with a 10-microsecond pulse at the same level. The command code lines are set for either an X position, Y position, or command word. The code is put on-line, and a strobe pulse is sent. The command code can then be changed, and another word can be sent. The interface outputs are monitored by the LEDs in series with the output lines. Connections to a compatible interface or shorting plugs must be in place to use the LED indicators. Representative addresses are commanded, and the LED indicator output is observed to demonstrate that the input command is echoed in the position returned. Command codes are verified by observing that the trim speed is enabled in trim, and that the laser is controlled by the laser enabled and laser not inhibited commands.

Laser Status. - The laser status signals were verified by introducing laser faults and observing LED indicators.

2.5 MODULATOR DESIGN

Figure 5 shows a detailed block diagram of the signal processing circuitry to be used in testing ECOM Oscillator Assemblies (06006415). Relative signal levels are shown in (dB). They indicate signal levels at selected points in the circuitry with respect to a reference signal sample input from the Load Chamber probe antenna. The absolute power levels shown in parenthesis are in (dBm) and represent the nominal[1] power levels expected at critical points in the circuitry. The probe antenna is assumed to have a 0dB net gain and maintain a vswr of 1.5:1 or less over the operating band[2].

2.5.1 Oscillator Sensitivity Test Concept

The design goal of this program is to set oscillator "sensitivity" to within ±0.5 percent of a specified nominal value. That is, all unpotted production oscillator sensitivities shall be set at a fixed voltage ±.5 percent after trimming[3]. (The value of the fixed voltage has not yet been determined.) The average test and tune time (excluding mechanical indexing) shall be less than or equal to 1.2 seconds/unit.

To achieve this goal, a system has been devised (see figure 5) whereby maximum use is made of the resolving power and accuracy of the HP 21MX Computer Series A/D and D/A Converters (HP 12751A and HP 12757A, respectively). These converters have resolutions of 12 bits, including sign, LSB=5mV. Overall accuracy is approximately 0.11 percent.

The test and tune approach can be summarized as follows:

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(1) Verified by experimental data taken with a dipole probe antenna in close proximity to the Load Chamber walls.
(2) Experimental data using a dipole probe indicates the feasibility of these values.
(3) Note that pre-tune sensitivity can exceed a range of 2 to 1.

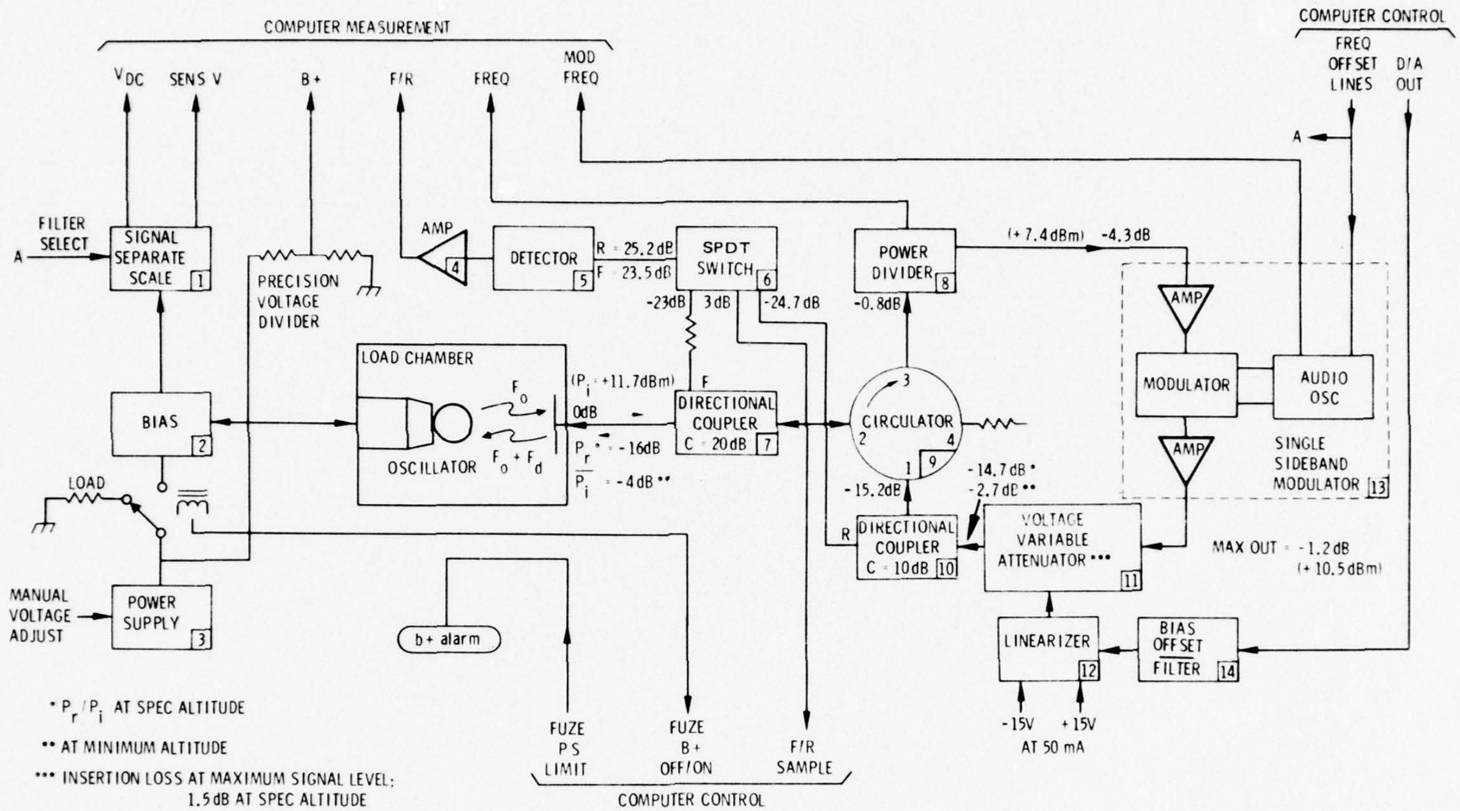

Figure 5. Modulator

2.5.1.1 System Calibration by Standard Oscillators. Pre-calibrate the overall Modulator/Load Chamber loop gain using several "standard" oscillator assemblies whose sensitivities have been previously determined[(4)]. (The computer sets the loop gain while observing output sensitivity. It stops when the measured value of sensitivity equals the assigned value.) The "standards" will be equi-spaced across the normal carrier frequency range for this oscillator design. The computer calculates and memorizes the ratio of reflected to incident power plus actual oscillator carrier frequency for each "standard" after automatic loop gain adjustment. This is done for each "standard" oscillator across the specified operating frequency band.

2.5.1.2 System Test and Trim. Individual units will be trimmed after noting carrier frequency and adjusting overall Modulator/ Load Chamber loop gain to the memorized value for a given test oscillator carrier frequency[(5)]. Once this is accomplished, the test and trim sequence can commence. (See Section 2.5.2 for a more detailed description of the test and trim cycle.)

2.5.1.3 Comments on Modulator System Approach.

a. Setting the ratio of reflected to incident power in the modulator for each test oscillator frequency eliminates the problem of gain (or insertion loss) variations of the individual rf components over frequency, temperature, and time. Loop gain

---

(4) "Standards" will be measured using an independent free-space measuring technique and sensitivity values assigned to each "standard" oscillator before Modulator/Load Chamber calibration. Since the present primary measurement method is only accurate to about ± 10 percent, all new oscillators will be set to V $\pm .5$ percent based on assigned values instead of on an absolute basis. The test and trim equipment should be reproducible to a ± 0.5 percent as a design goal.

(5) Interpolation of loop gain will be required for oscillators at frequencies between "standard" frequencies. The electrical distance around the modulator loop will be minimized to reduce off frequency ratio deviation.

setting accuracy is, therefore, dependent only on the short term accuracy and resolution of the a/d converter used in adjusting this ratio[6] plus potential errors in the individual detected signals in the modulator resulting from residual vswrs of individual rf components. Calculation error is negligible in this case.

b. Care in the selection of rf components has been taken to assure adequate vswr, directivity, and isolation of individual items. Components have been selected and layout proposed which virtually eliminate errors of this sort with minor exceptions.

Even if small error signals of this nature are introduced in the reflected or forward power signal arms, the percentage detector output error will be consistent for any given frequency and independent of power level. Since the "standard" reference ratio includes the same error, a return to the "standard" ratio during test assures repeatability in gain setting. In effect, errors of this type are virtually eliminated.

An example of this type of error is the band edge reflection of the Load Chamber probe antenna to return signals from the single side-band modulator. (The in-chamber vswr will be no greater than 1.5:1.) For an input-incident signal-level reference of 0dB at f_o, the return signal at $(f_o + f_d)$[7] will be 16dB less when the modulator loop gain is set properly. The reflection to energy at $(f_o + f_d)$ at the probe, is therefore, an additional 14dB below that for a total of 30dB signal to "noise". Both signals couple

---

(6) HP states an overall accuracy of about 0.11 percent $\pm 1/2$LSB for each measurement. About one-half of the 0.11 percent is the result of long term drift and the remaining noise, etc.

(7) f_o = carrier frequency; f_d = single-sideband offset frequency.

to the forward detector. Since the detector has near square law characteristics, the undesired signal introduces about a 0.1-percent error in the total detector dc voltage output[(8)]. This added error, however, will be the same as that of the "standard" at the same frequency. When the computer adjusts reflected to forward power ratio, before a test and tune cycle, the resulting ratio will include the same error experienced by the "standard" modulator loop gain. Setting accuracy is, therefore, the same as the "standard".

A second potential error results from the finite side arm vswr of both forward and reverse directional couplers in conjunction with the finite vswr of the switch and combiner combination. Both primary and undesired reflection signals are at the same frequency (f_o or $f_o + f_d$, depending upon which coupler is involved). As in the first example, this error signal will be the same when measuring "standard" or test oscillator signals, effectively eliminating the potential error when resetting modulator loop gain ratio.

c. A third class of potential error signals occurs as a result of the undesired sideband and carrier outputs from the single-sideband modulator. With proper design, a single-sideband modulator can attain a minimum of 25dB rejection of carrier and undesired sidebands at the band edges in this frequency range. This introduces a potential error of about 0.3 percent per undesired sideband in the measurement of the return signal in the reverse coupler. Fortunately, however, these error signals are identical (or nearly so) in both test and "standard" oscillators at or near a specific frequency. Therefore, as in the previous case, they are effectively eliminated for setting the modulator loop gain ratio with respect to the "standard". These signals are negligibly low in the sampling of the forward signal.

---

(8) The mixed product detector output at (f_d) has considerably less conversion efficiency than the direct dc output causing a neglible added error. The computer could also eliminate this additional audio component if necessary.

d. Undesired carrier and sideband outputs also affect the measurement of oscillator sensitivity. Since the oscillator receiver-detector is fundamentally a peak detector[9], an error signal is introduced in the oscillator detector output of about 5.6-percent per undesired spectral line. The total detected signal from the test or "standard" oscillators in this electrical environment will be the desired sinusoidal output at f_d plus the low-level harmonics of f_d resulting from the undesired sideband outputs from the single-sideband modulator. If these undesired outputs were not there, a pure sinusoidal detector output would be observed in the test oscillator.

Elimination of errors introduced by the single-sideband modulator's higher order undesired sideband will be accomplished by filtering the oscillator detector output, as shown in the Signal Separate and Scale block (block 1 in figure 5), and/or performing a real-time Fourier Transform of the actual detector output voltage to extract the desired fundamental signal. The rms value of this fundamental signal determines the "sensitivity" of the test and "standard" oscillators.

The single-sideband image-frequency output (also at f_d) is another story. Minimization of the effect of this spectral line can be accomplished in one of two ways:

1. Determining, by pre-calibration measurement, its relative size over the one or two dB dynamic range of the single sideband modulator input (at f_d) and analytically removing this error from the results of the Fourier Transform of the test oscillator output.

2. Adjusting the total electrical distance throughout the modulator loop to produce a frequency modulation component at the oscillator detector diode at mid-band, removing amplitude modulation perturbations resulting from the lower sideband.

---

(9) Producing a detected audio output proportional to the phase summation of desired plus undesired sideband outputs.

The latter appears as the simpler of the two approaches. The final technique to be used will be determined in the next quarter.

e. Use of a single detector-amplifier combination, setting the detected signal levels to approximately equal amplitude and calculating signal ratios, instead of individual signals, eliminates the errors introduced by nonlinearity in the detector and possible detector-amplifier gain variations as a function of time. This approach also circumvents the problem of oscillator output power variations from unit to unit.

f. Signal scaling to about 10-volts peak will be provided for each computer test signal output minimizing measurement errors due to the finite resolution of the computer a/d converter. This also minimizes the error resulting from noise on the inteconnecting cables from modulator to computer.

g. Periodic computer monitoring of the test oscillator power supply and single-sideband modulator absolute-offset frequency will be performed by computer control to assure repeatable results and accuracy in calculation of fundamental oscillator sensitivity.

2.5.1.4 Modulator Versatility. - Present plans are such that the test oscillators will be stimulated by an accurately controlled burst of rf energy of constant amplitude at a frequency of (f_o + f_d)[(10)]. Both amplitude and pulse duration will be computer controlled via the voltage variable attenuator and linearizer shown in the schematic. Accurate computer monitoring of the return signal level before test and trim assures repeatable results.

The voltage variable attenuator-linearizer combination has a 55dB dynamic range allowing the computer to provide near-continous

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(10) Mid-band doppler frequency only. High- and low-band edge doppler frequencies are also provided to increase modulator versatility. These, however, will not be used for present tuning plans with constant amplitude bursts.

adjustment of return signal levels providing oscillator test signals of variable amplitude as a function of time. This added feature allows for optimizing test signal modulation wave shape as the program develops and more important allows for stimulating, testing, and tuning oscillator-amplifier combinations using M-waves or other more compact test signals. It is felt that this latter feature ultimately will produce cheaper more consistent oscillator-amplifier combinations.

2.5.2 Oscillator-Trim Time Sequence

The time sequence for testing and trimming oscillators is shown in figure 6. The absolute times indicated are estimates only, since actual computational time awaits completion of the development and programming of the equations needed for determining capacitance selection.

The test and tune portion of this sequence consists of a short modulator "calibration" period, three "tune" periods, and a "final test". A precise five second warm-up period will be provided to allow for oscillator parameter variations as a result of transistor junction heating. The begining of each "tune" sequence will be fixed with respect to B+ turn-on since the test oscillator parameters continue to drift for a considerable time beyond five seconds. By setting specific test times from a cold start after B+ turn-on, repeatability is enhanced to the best degree possible. It should be noted that a "sensitivity" measurement at about five seconds from turn-on is near optimum for normal operation.

2.5.2.1 Ceramic Chip Tuning Capacitors. A 4-bit 2.25pfd binary capacitor has been designed for stepwise adjusting oscillator "sensitivity". Two identical capacitors of this value are included on a single ceramic substrate to adjust "sensitivity" up or down, as required.

2.5.2.2 Differential Sensitivity Variations. - Unfortunately, a specific percentage change in tuning capacitance produces a variable percentage change in sensitivity from unit to unit,

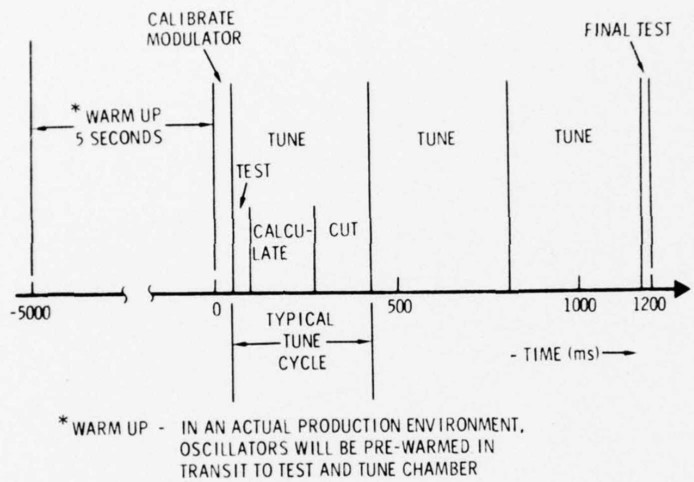


Figure 6. Oscillator-Trim Time Sequence

depending upon circuit component parameters. Although the average shift in sensitivity is predictable, the shift from unit to unit varies well beyond the ± 0.5 percent design goal requirement. To minimize this problem, at least two cuts, and possibly three, will be required and the "before" and "after" cutting sensitivities will be used to modify the differential capacity-sensitivity equations to better predict sensitivity changes of the individual units.

Figure 6 shows three tuning cycles. The first provides for a stepwise sensitivity change. The second and third provide continous change by cutting a specific calculable area from the remaining capacitors. Since the differential capacitance-sensitivity equations converge, the value of capacitance to be removed during the second and third trials should be small in comparison to the initial stepwise cut.

2.6 MECHANICAL DESIGN

During this report period, the Mechanical Engineering effort was directed toward the completion of all assemblies and parts needed for the acceptance test of the laser system. In addition, effort was directed toward the completion of subassemblies and parts needed for taking electrical response data in the RF Load Chamber. A fixture, which enables testing of the modified oscillator assembly in the existing HDL RF Load Chamber, as well as in the new chamber, has been designed and fabricated. Also, the room layout was completed, the laser and computer systems were installed, and the work area was equipped with safety signs and safety warning lights for personnel protection.

The laser table was modified to accept the RF Load Chamber and the laser unit was placed on a platform structure to elevate the unit for optimum operator height during loading and unloading of the chamber.

2.7 SIMULATION AND PROGRAMMING

The simulation of the real-time amplifier test program was 90 percent completed. A flow chart of the program was given in the last report and is shown herein as figure 7.

To simplify the writing and debugging, the program was divided into a main-line program and subroutines.

The following calculations were assigned to subroutines:

1. Least mean square fit to detector data to obtain threshold and current generators.
2. Discrete Fourier Transform to calculate amplitude.
3. Step response of filter.
4. Impulse response of filter.
5. Convolution integral.
6. Required length of cut for given change in gain.

The main-line routine has been coded and debugged. Subroutine 1, 3, 4, and 6 have been coded, debugged, and checked out with the main-line routine.

The i/o subroutines that are not yet coded were defined within the program. Nominal values for the variables have been entered; thus, the main program was completely checked out using the subroutine calls.

It is expected that most of the code for the simulation will be used for the actual real-time program. The i/o driver routines, however, will have to be written specifically for the Hewlett-Packard computer. Appendix A provides a complete specification for the program, and Appendix B provides an integration specification.

2.8 SUBSYSTEM INTERFACE

During the past quarter, a set of cables was constructed to interconnect the computer, laser trimmer, and modulator. These cables join in a third rack cabinet, at an interface panel that will

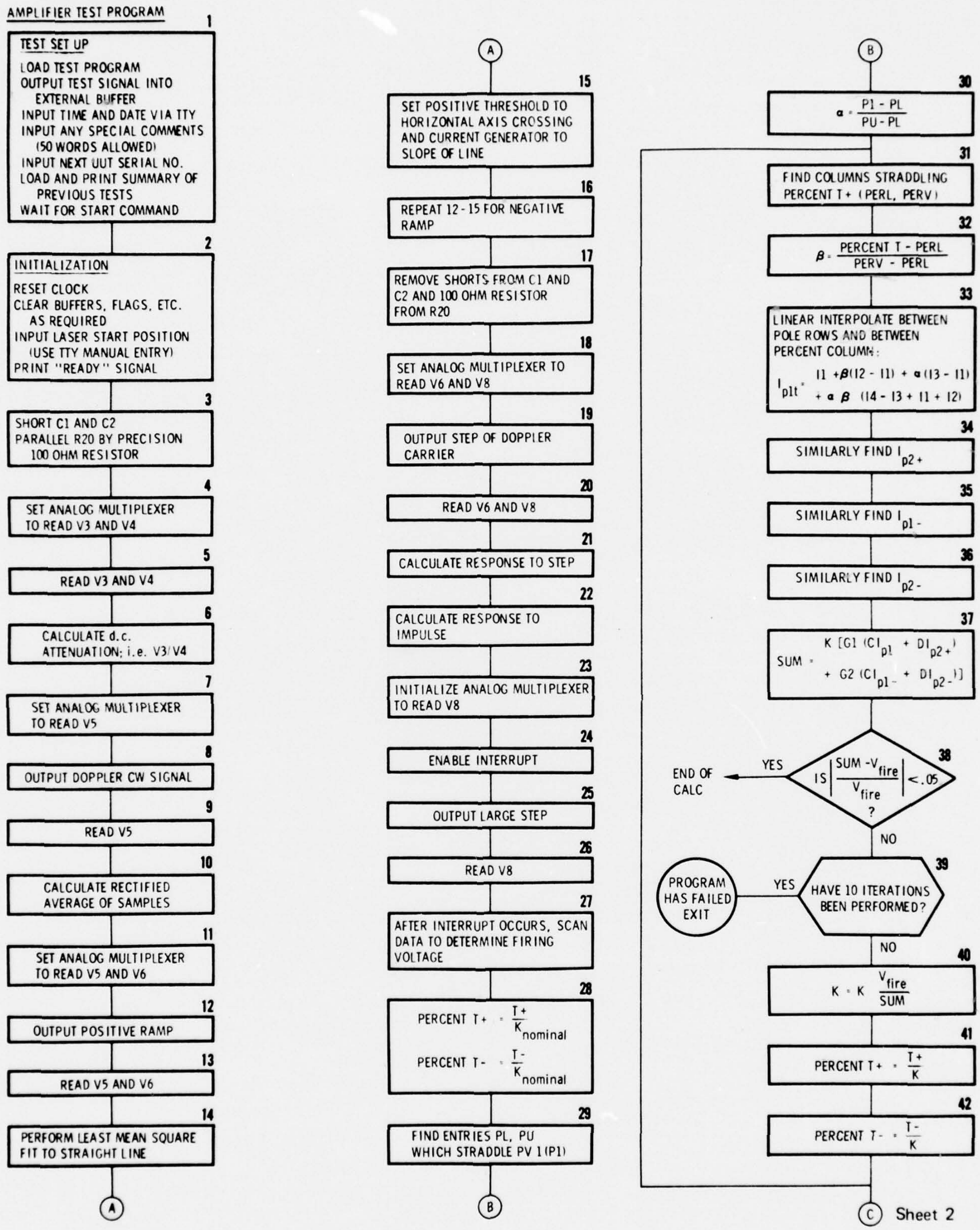


Figure 7. Amplifier Test Program (Sheet 1)

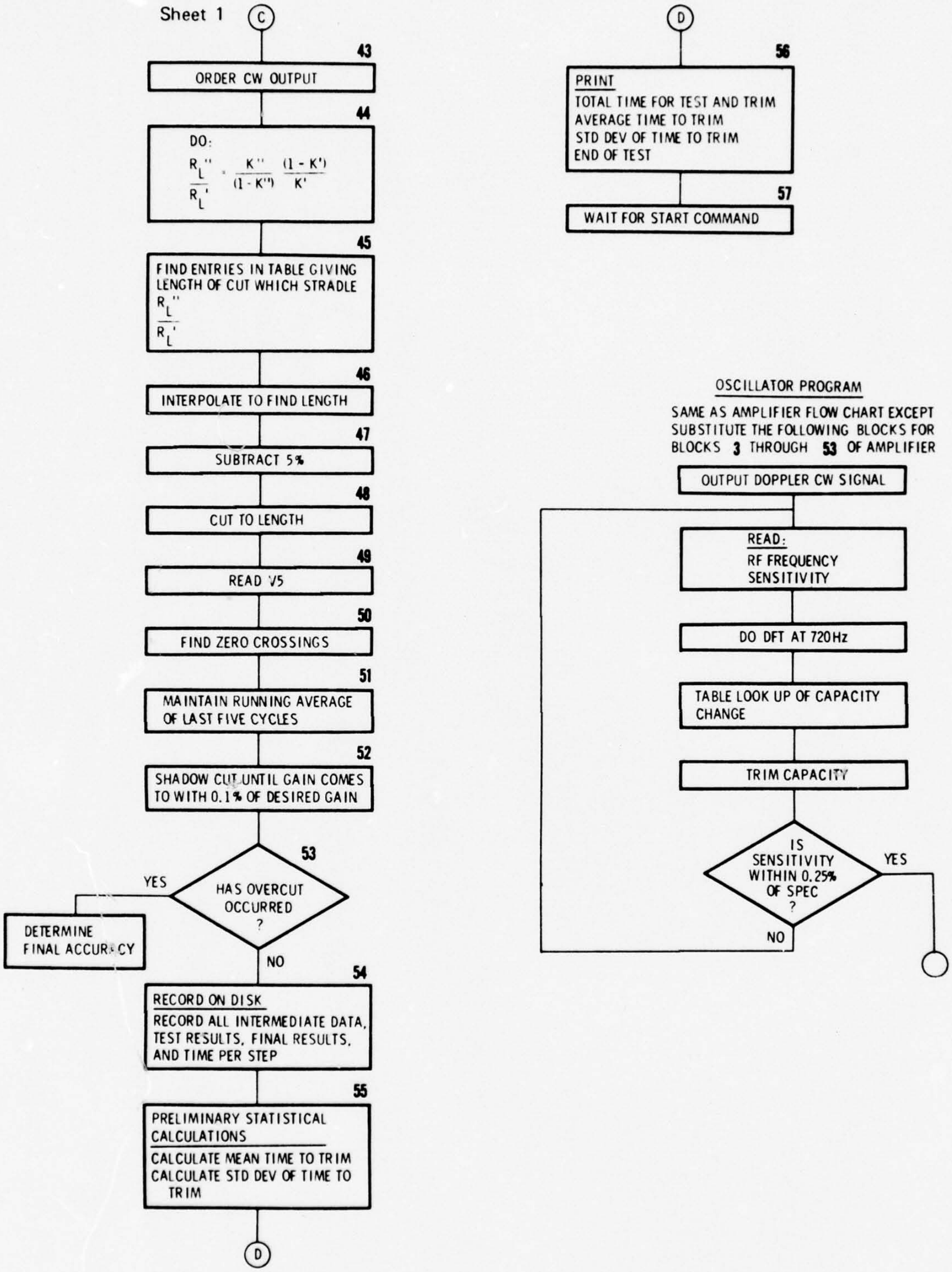


Figure 7. Amplifier Test Program (Sheet 2)

also contain an optical isolator board to assure high isolation between computer and laser-trimmer equipment. This opto-coupler board has been constructed and bench tested.

A yellow safety light has been wired to illuminate whenever the laser supply is on, and a red flashing light has been activated when the laser pump lamp is energized.

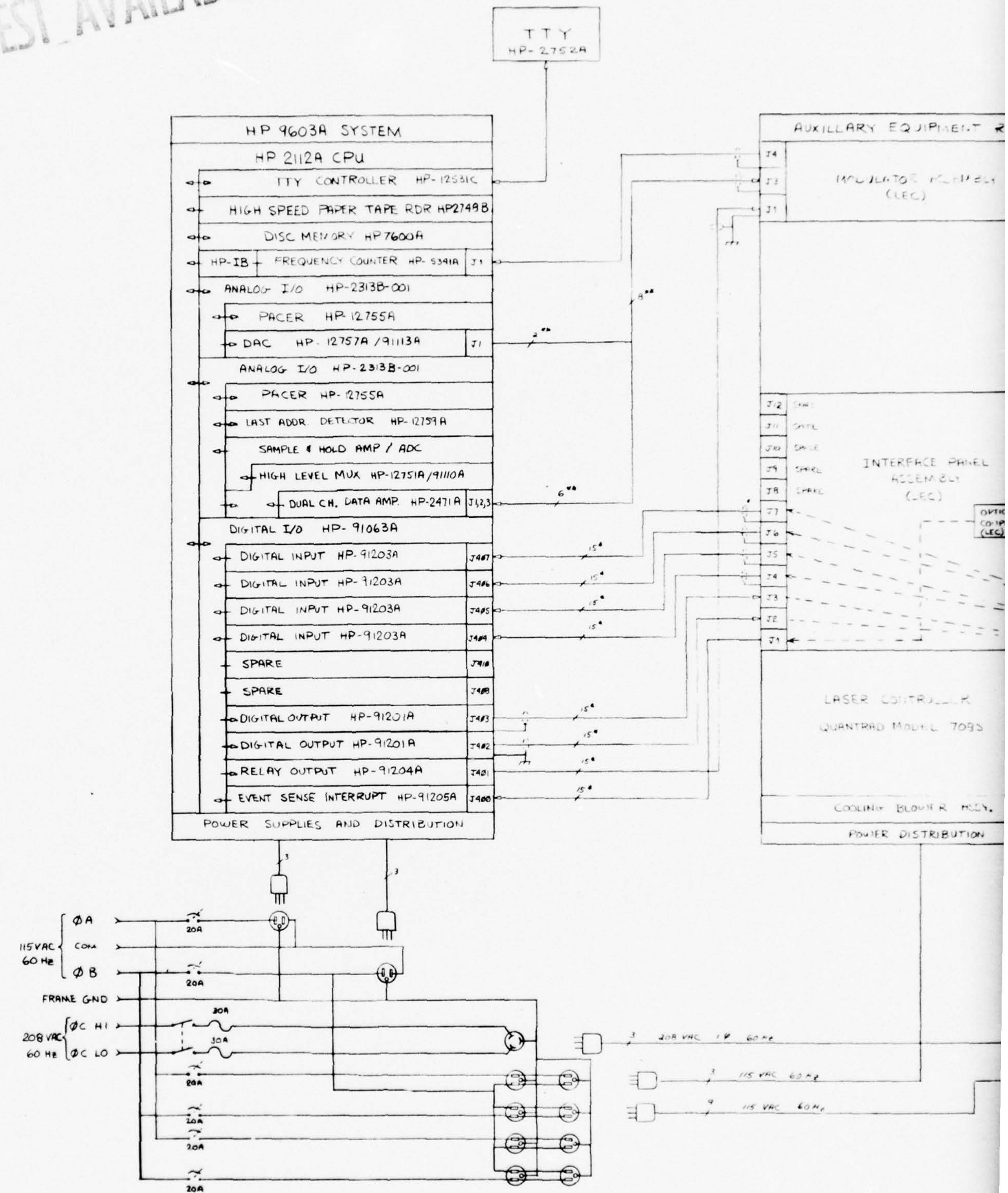
The specification of the computer output sequence for laser control was also completed. The computer interfaces with the laser-trimmer through a multiprogrammer unit and all signals are optically coupled.

Parts orders are about 95 percent complete with 2 Hewlett-Packard disc packs and an HP differential cable still outstanding.

The operation of the laser electrical interface was demonstrated by the vendor. Figure 8 is a complete diagram of the ECOM test station indicating the interfaces and cabling.

2.9 OSCILLATOR MODEL

Since the last report, computer models have been used to trim approximately 900 production fuzes on another project. The results are summarized in figure 9. Each line in the figure represents the history of a lot of approximately 100 fuzes. The trial number along the abscissa represents the number of test and retrim cycles that were necessary until the percentage of fuzes given by the ordinate met the specification. The curves marked "NLM13A" represent lots that were trimmed according to the predictions of the computer program as described in previous reports. The specification (±10 mV from a 126-mV nominal value) was more severe than that used previously (±15 mV) so that the initial success ratio was correspondingly lower. The salient feature of these graphs is the appearance of "convergence"; i.e., the success ratio increases with successive trials. (Exceptions occur only when the initial success ratio is relatively high. In these cases,



TTY
HP-2752A
HP 9603A SYSTEM
HP 2112A CPU
TTY CONTROLLER HP-12531C
HIGH SPEED PAPER TAPE RDR HP2749B
DISC MEMORY HP7600A
HP-IB
FREQUENCY COUNTER HP-5341A
J1
ANALOG I/O HP-2313B-001
PACER HP-12755A
DAC HP-12757A/91113A
J1
ANALOG I/O HP-2313B-001
PACER HP-12755A
LAST ADDR. DETECTOR HP-12759A
SAMPLE & HOLD AMP / ADC
HIGH LEVEL MUX HP-12751A/91110A
DUAL CH. DATA AMP. HP-2471A
J1,2,3
DIGITAL I/O HP-91063A
DIGITAL INPUT HP-91203A
DIGITAL INPUT HP-91203A
DIGITAL INPUT HP-91203A
DIGITAL INPUT HP-91203A
SPARE
SPARE
DIGITAL OUTPUT HP-91201A
DIGITAL OUTPUT HP-91201A
RELAY OUTPUT HP-91204A
EVENT SENSE INTERRUPT HP-91205A
POWER SUPPLIES AND DISTRIBUTION
AUXILLARY EQUIPMENT R
MODULATOR ASSEMBLY
(LEC)
INTERFACE PANEL
ASSEMBLY
(LEC)
LASER CONTROLLER
QUANTRAD MODEL 709S
COOLING BLOWER ASSY.
POWER DISTRIBUTION
J4
J3
J1
J12
J11
J10
J9
J8
J7
J6
J5
J4
J3
J2
J1
SPARE
115VAC
60 Hz
ØA
COM
ØB
FRAME GND
208 VAC
60 Hz
ØC HI
ØC LO
20A
30A
208 VAC 1Ø 60 Hz
115 VAC 60 Hz
115 VAC 60 Hz

2

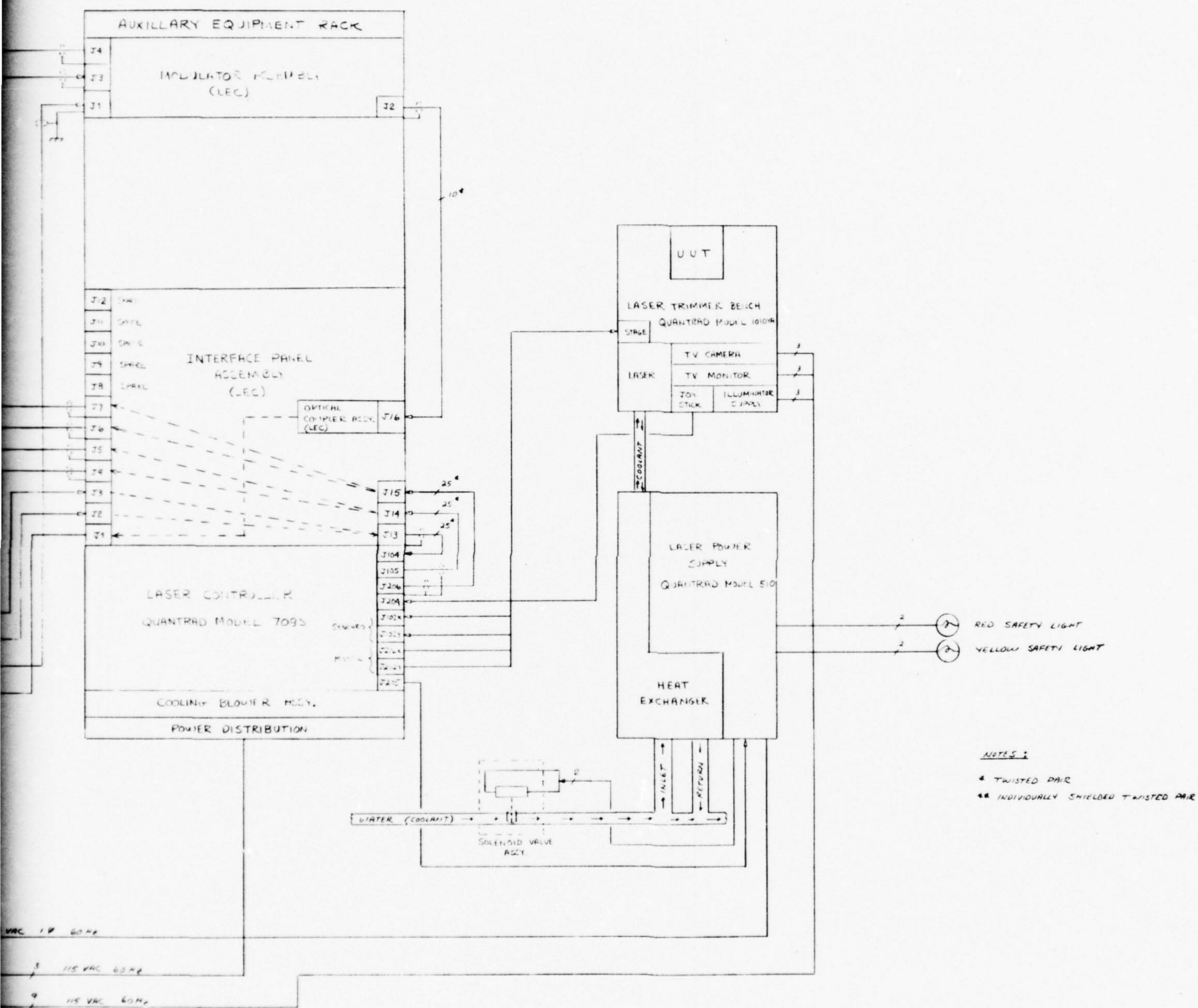


Figure 8. ECOM Test Station

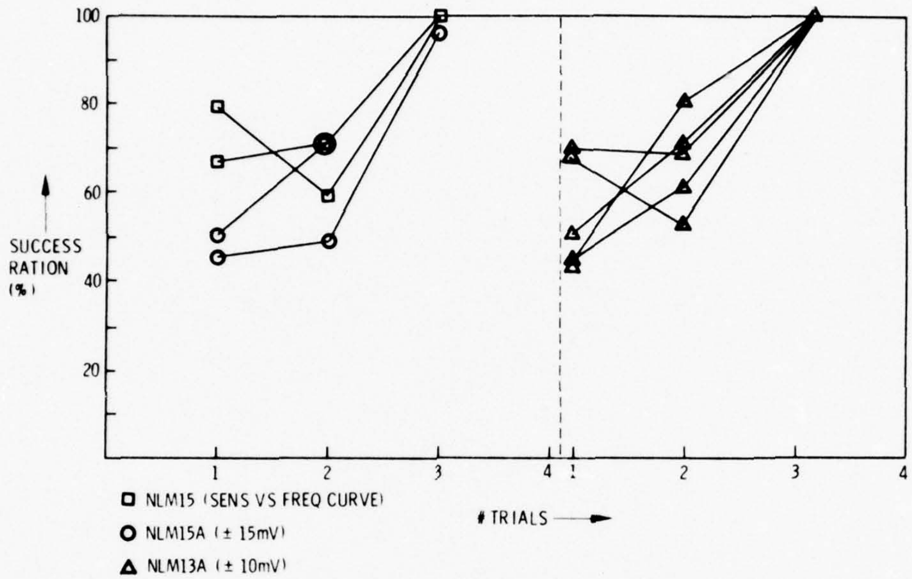


Figure 9. Oscillator Model Results

the number of oscillators available for subsequent trials is relatively low, and the variations in the success ratio from this point on are probably less significant because of statistical fluctuations.)

The convergence properties of the model are particularly important for the series of test and trim procedures of the current program. It is important to note that the "convergence" suggested by the curves in figure 9 is not exactly the same type that will be necessary in the ECOM testers. For production purposes there was no serialization of fuzes. If a fuze was still out of specification after the first trimming, the new data was fed into the computer as if it were a brand new fuze. The computer had no memory of either the original data or the original prediction. If provisions for such feedback were to be made it is clear that the convergence would be much faster than that indicated by figure 9. (The reason that convergence without feedback occurs at all is because the difference between the measured and the desired sensitivity tends to decrease with successive trials; in other words, when the computer is in error, the error is sufficiently small so that the success ratio increases on the next trial.)

The principal reason for expecting much faster convergence when feedback is provided can be described by referring to figure 9, where the initial success ratio is seen to vary considerably from one lot to another. The nonlinear model, described previously (i.e. NLM13A) has the ability to "respond" to different lots of transistors, which may be characterized by different ranges of s-parameters, because the model recalculates the nonlinear curve based on the measured data for each transistor. However, the values of the circuit parameters are assumed to be identical for all oscillators. In practice, this is not the case; variations in materials and etching tolerances can produce significant variations in circuit capacitances and inductances, and it is such variations from lot to lot (as well as from unit to unit) that cause the behavior shown in figure 9. If the initial data

were retained in memory and compared with similar measurements for another configuration of the same fuze, it would be possible to recalculate, for example, C_o (See figure A-1 of the Second Quarterly Report), and thus account to some extent for circuit variations as well as for transistor variations. The result would not only be faster convergence, but a reduction in scatter for a given trial. Modificiation of the program to accept feedback data and the testing of this assumption is planned for the next reporting period.

Four of the lots were tested against a different type of program (NLM15 and NLM15A). These programs have no physical model as a basis, such as that of NLM13. Instead, these programs are based on the observation that to a certain extent change in sensitivity is a function only of an initial and final pad condition. Data on previous tests are fed into a data file and used to determine the average value of this change for each pair of conditions. This value is assumed to hold for all subsequent oscillators; only the measured sensitivity and the pad condition under which the measurement was made are needed for a prediction of the optimum pad selection for meeting the specification. The advantage of these programs is a marked reduction in process time. Unfortunately, due to various circumstances, these empirical algorithms were used under a set of specifications that were different than those used for NLM13A, and therefore the results are not directly comparable. More decisive comparisons of the two types of models are planned in the near future.

3. CONCLUSIONS

Objectives of the third quarter were met as follows:

- The major test station subsystems were delivered, and tested at LEC.
- A major portion of the fuze components were received.
- A simulation of the main-line routine of the amplifier test program was 90 percent completed.
- The modulator design was completed.

4. PROGRAM FOR NEXT QUARTER

During the next reporting period, the following activities are planned:

- Complete subsystem interfaces.
- Integrate the complete system.
- Initiate coding of the real-time program on the test system.
- Continue fuze-prototype fabrication.
- Continue simulation effort.
- Order modulator components.

5. PERSONNEL

During this reporting period, the following personnel worked on this program for the number of hours indicated.

Name	Program Function	Hours
A.J. Eisenberger	Program Manager	112
P. Kaszerman	System Engineer	384
R.F. De Mattos	Tester RF and Fuze	185
H.J. Curnan	Laser Trimmer and Fuze Microcircuits	40
G.L. Freed	Digital Components	128
U.Z. Escoli	Mechanical Design	139
A.H. Owens	Mechanical Design	8
R. Blau	Computer Modeling	8
-	Draftsmen, Machinists, Technical Publications, etc.	723

APPENDIX A

SPECIFICATION FOR REAL-TIME PROGRAM TO

TEST AND TRIM M732 FUZES

CONTRACT DAAB07-76-C-0032

ISSUE 1 (March 30, 1977)

Prepared by: P. Kaszerman

P. Kaszerman

Reviewed by: Steven Feldman

S. Feldman

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1.0 INTRODUCTION

This specification describes the real time functions required to test and trim M732 fuze components. It covers the following items:

- Amplifier Test and Trim
- Oscillator Test and Trim
- BITE

For the purpose of completeness a description of the test stand, M732 fuze operation, and fuze components, in addition to the program specification, are included.

2.0 SYSTEM DESCRIPTION

The test station system design is an extension of third-generation design principles. It contains the following basic elements:

- Computer control
- Computer-generated stimuli
- Computer-controlled sampling system
- Computer-controlled interface
- Computer calculation of parameters from sampled data
- Computer controlled laser trimmer

An important addition has been made to the third generation system in the form of the computer-controlled, real-time, trim capability. A laser trimmer was chosen to perform this function. This unit, under computer control, is capable of either trimming thick-film resistors and capacitors or cutting printed wiring leads to disconnect discrete components. Thus, in addition to being automatically tested, units can be tuned or trimmed to bring them within specified limits.

Hewlett-Packard Equipment

The system concept is shown in Figure 2-1. Specific hardware has been chosen to implement this system. All the major hardware, except the laser, are catalog items from Hewlett-Packard. Figure 2-2 is a block diagram in which the major components are shown. The letters in the lower corners of each unit, in this figure, relate to equipment listed in Table 2-1. This table is a list of the catalog items with their catalog numbers. Referring to Figure 2-2, it is seen that the central computer is a Hewlett-Packard 2112A unit. This computer is a 16-bit minicomputer. It is being purchased with 32K of memory, which minimizes the need for program overlap during real-time operation. The computer will come with firmware for multiply/divide, floating-point arithmetic, double-precision arithmetic, 14 multiplexed I/O channels, an internal clock, and two DMA channels. A control panel is provided on the computer. This panel, in conjunction with the TTY, will provide the operator interface during program development and actual testing.

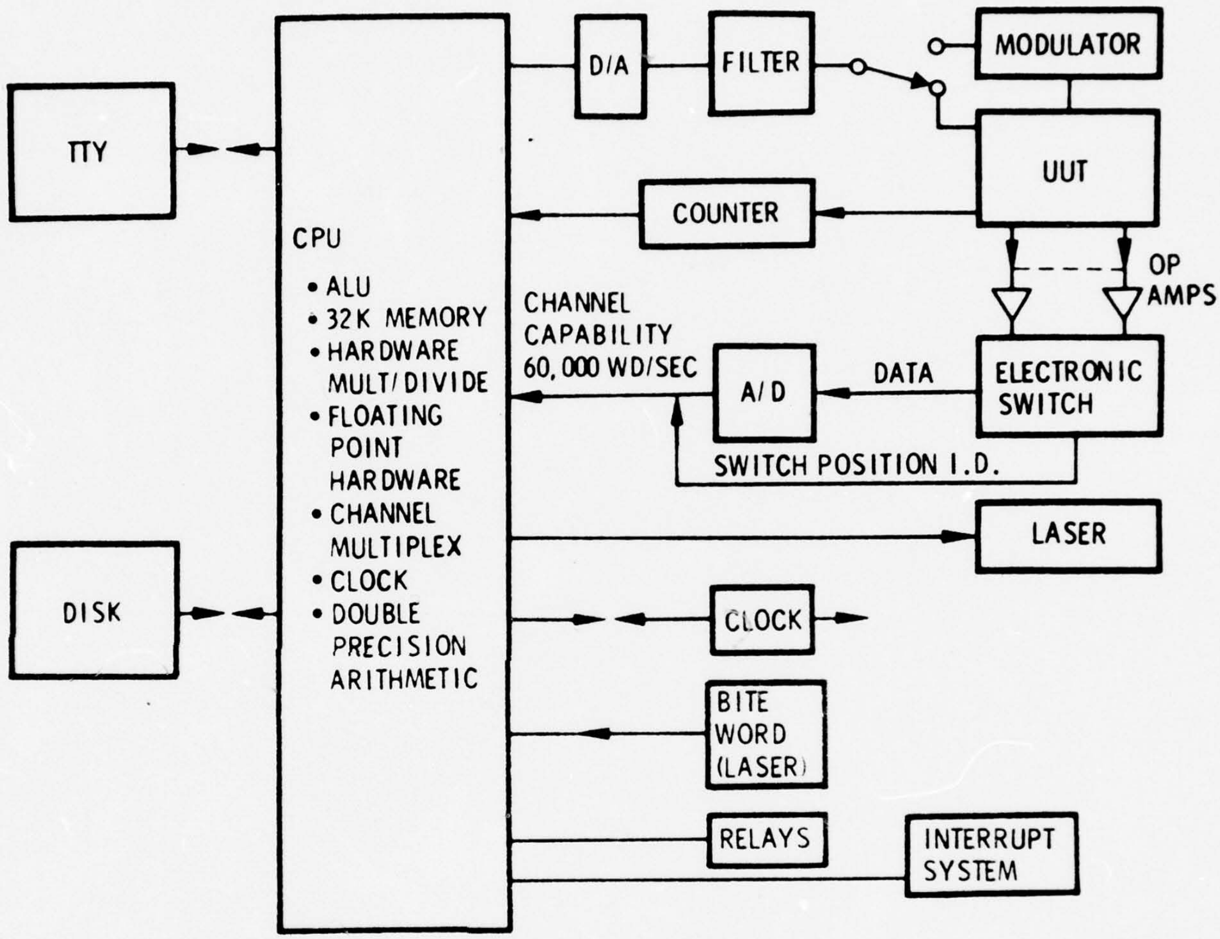


Figure 2-1. Test and Correction System

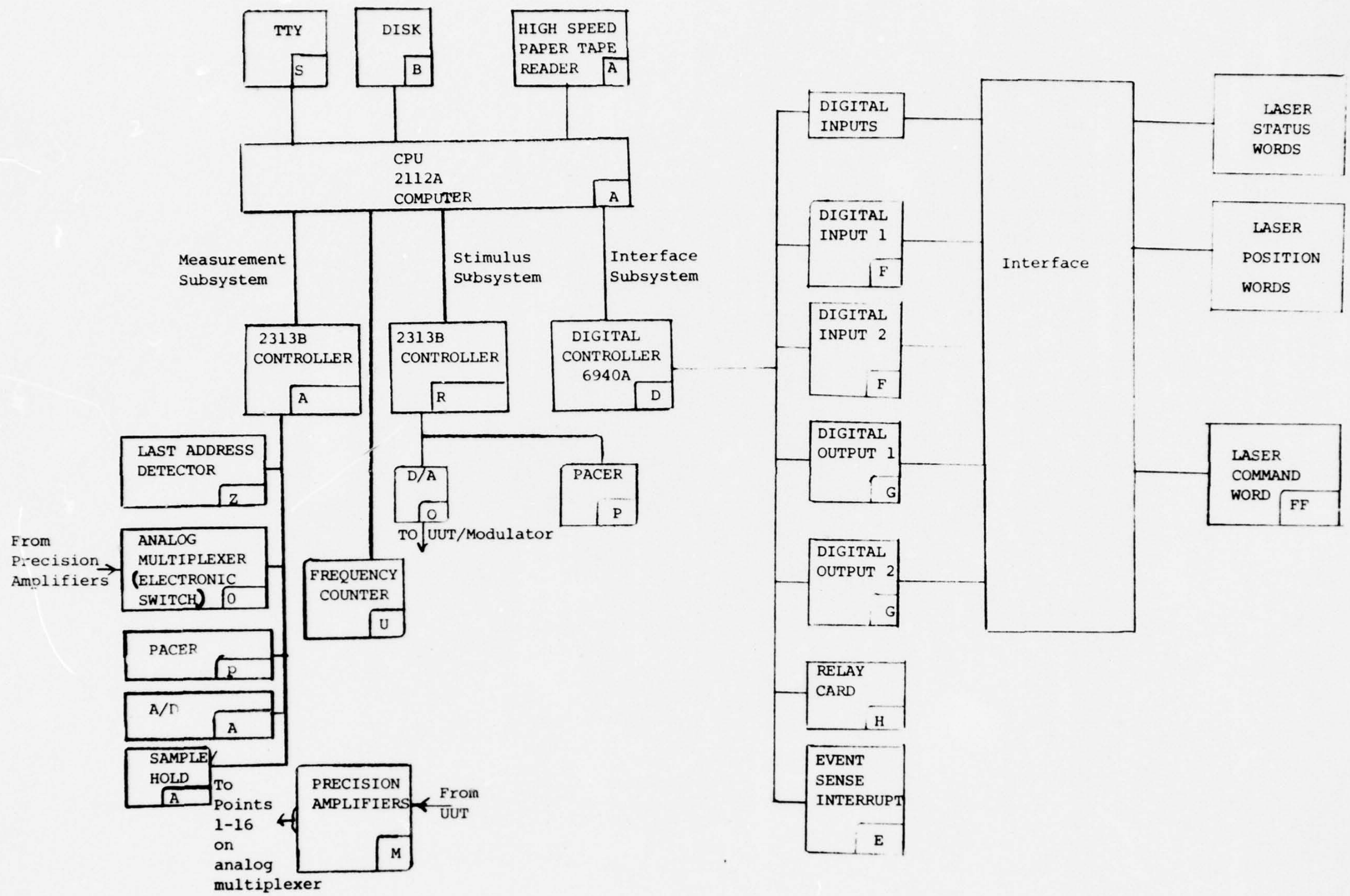


Figure 2-2

Computer and Computer Peripherals

The operating system consists of a 4.9M byte disk, a paper tape loader, and the associated real-time executive programs. The disk will also provide storage for all the real-time programs. Data logging will be on the disk.

The stimulus subsystem starts within the computer itself. Either by program or external entry, a table is made to describe the shape of the desired stimulus waveform. Upon program command, this table is outputted through a DMA channel to the Hewlett-Packard 2313B Controller (labelled R in Figure 2-2). In turn, the controller routes the words to a 12-bit D/A converter. The stimulus system is capable of outputting digital words at a rate limited by the DMA channel (i.e., 600,000 words/minute). The D/A converter is capable of a settling time of 20 microseconds. The output rate is controlled by the pacer (P in Figure 2-2) which is programmed by the computer.

The measurement system starts with the precision amplifiers (Unit M) shown in Figure 2-2. The amplifier outputs are routed to the analog multiplexer labelled O in this fugure. In effect, the multiplexer is part of the switching system, since it is programmed by the computer to sample from 1 to 16 consecutive positions and then to repeat these sample continously. The multiplexer can also be used in a mode in which a sequence of arbitrary positions, stored in the computer, will be executed.

Table 2-1

Major Purchased Items

Hewlett-Packard Catalog Items for Tester

Item	Quantity	Description
A.	1	HP 9603A High-speed Measurement and Control System.
B.	1	Option #A03: RTE-II with 4.9M Byte Disc, Cabinet, Fortran IV, System Libraries.
C.	1	Option #Y13: Batch Spool Monitor.
D.	1	Option #T17: 6940A (91063A) Digital I/O Subsystem.
E.	1	Option #J17: Event Sense Interrupt.
F.	2	Option #J16: Isolated Digital Input, 12 bits.
G.	2	Option #K04: TTL Output, 12 bits.
H.	1	Option #K05: Relay Output Card.
I.	1	Option #P24: Replace 2108A with 2112A.
J.	1	Option #R00: Teleprinter and Local I/O, 10 cps.
K.	1	Option #005: Additional I/O for 2313B.
L.	1	Option #021: 10 ft. Differential Cable.
M.	3	Option #025: 2471A Data Amplifier.
N.	1	Option #026: Case for 2471A Cards.
O.	1	Option #008: 16-Channel High Level Multiplexer.
P.	2	Option #011: Programmable Pacer (12755A).
Q.	1	Option #013: D/A Dual 12-bit Converter.
R.	1	Option #558: Second 2312B-001 Integrated into 9603A.
S.	1	Option #P12: 16K Word Memory Expansion.
T.	1	HP 59310B HP-IB Interface Card.
U.	1	HP 5341A Frequency Counter to 4.5 GHZ.

Table 2-1

(cont'd)

Item	Quantity	Description
V.	1	Option #002: Rear Panel Connectors
W.	1	Option #003: 1.5 GHZ Frequency Range
X.	1	Option #011: I/O ASCII Interface
Y.	1	Option #908: Rack Flange Kit; HP Part No. 05326-60046.
Z.	1	Last Address Detector
		Quantrad Corporation
	1	Laser Trimmer Model 1021

The output of the analog multiplexer is fed to a sample-hold and then to a A/D converter; from there, the DMA channel reads the words into the computer. A pacer (0) accurately times the transfer rate. Again, the pacer rate is set by the computer.

For the specified accuracy of ±0.09-percent full-scale, ±1/2 LSB the maximum rate into the computer is 45,000 words per second.

The Hewlett-Packard Digital Controller shown as Unit D in Figure 2-2 handles low-speed digital input/output. The output commands to the laser and the laser BITE word will run through this multiplexer. Additionally, the event sense interrupt is controlled by this unit. The event sense unit can be set to interrupt the computer, based on matching a bit reference word. Since there are 12 bits in the reference word, there are 2^{12} (or 4,096 independent events) that can interrupt the computer.

A relay card (Unit H) consisting of 12 single-pole, single-throw relays is also computer-controlled through the digital multiplexer. Additional relay cards can be inexpensively obtained. These relays, together with the analog multiplexer, form the computer-controlled interface. The frequency counter (Unit U) can read RF frequency up to 1.5GHz.

Except for the frequency counter, this system is essentially a low-frequency system. It is limited by the DMA rate to 600,000 words per second. However, the frequency range can be extended to include RF and microwave test and trim by adding external buffering, RF synthesizers, and an RF spectrum analyzer.

Laser Trimmer

General Description

The Model 1021 Laser Trimmer consists of the following major assemblies:

a. YAG Laser

b. Optical Subsystem

c. Beam Positioner

The laser is a high powered continuously pumped Nd: YAG Oscillator. It uses an acoustic-optic Q-switch to achieve short, high-power pulses of infra-red light which are useful in material removal applications.

The optical subsystem consists of optics which direct the laser beam (the beam positioner), provides for binocular viewing of the work area, and provides for viewing on a TV monitor. The beam positioner uses moving prisms to optically sweep the laser beam over the work area. The stage is motor-driven by commands from a customer-provided computer.

A functional block diagram of the trimmer is given in Figure 2-3.

Laser Description

General Description

The laser consists of two modules; the laser power supply and the laser head.

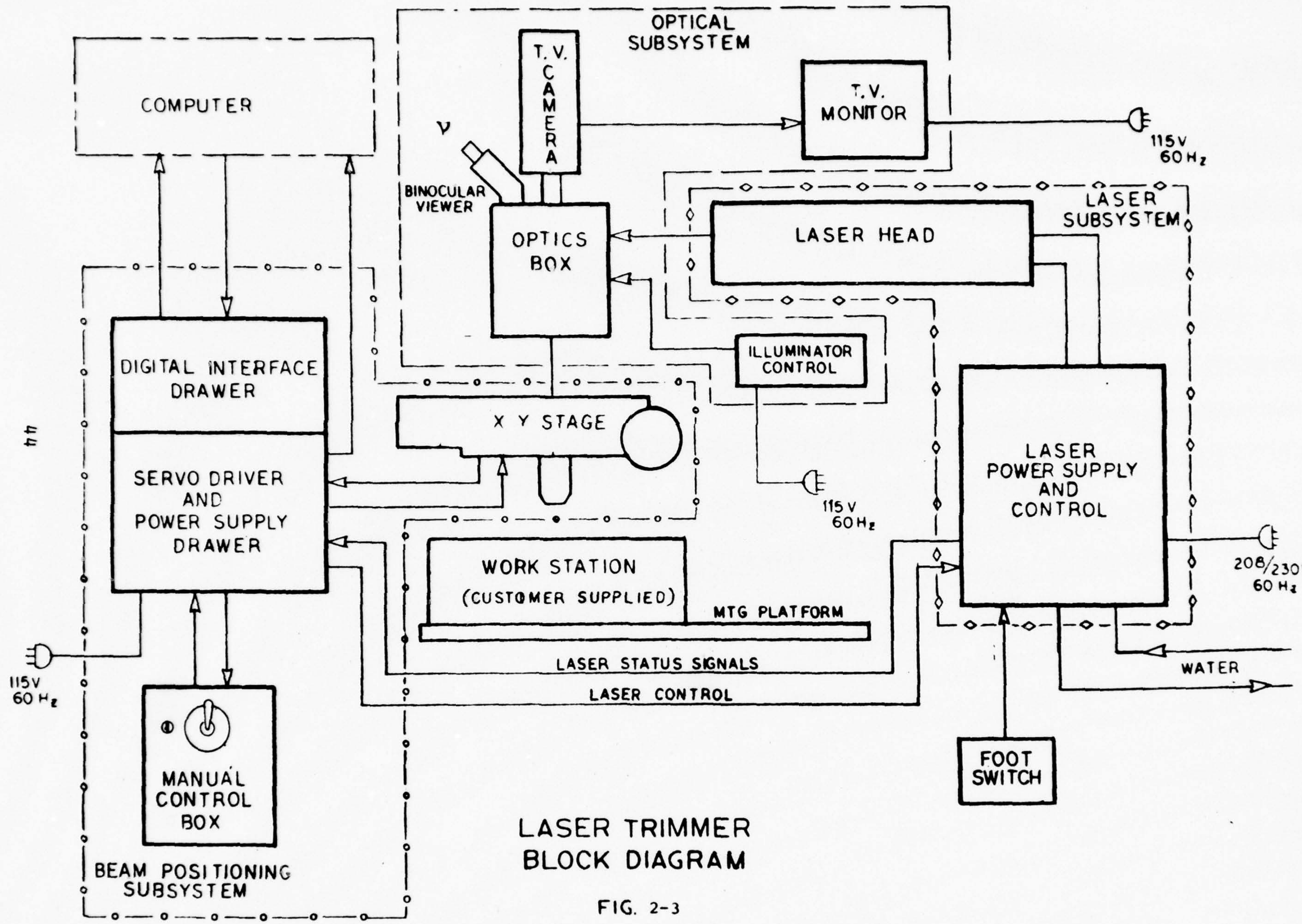
The power supply cabinet contains the pump lamp power supply, the RF driver for the acousto-optic Q-switch, the water-to-water heat exchanger, and the laser controls.

The head assembly consists of the laser pump cavity, the optical resonators, and Q-switch. A 2.5 KW krypton-arc lamp is used to optically pump the YAG laser rod. A safety shutter insures positive and quick shut off of laser output.

Figure 2-4 indicates the functional block diagram of the laser subsystem.

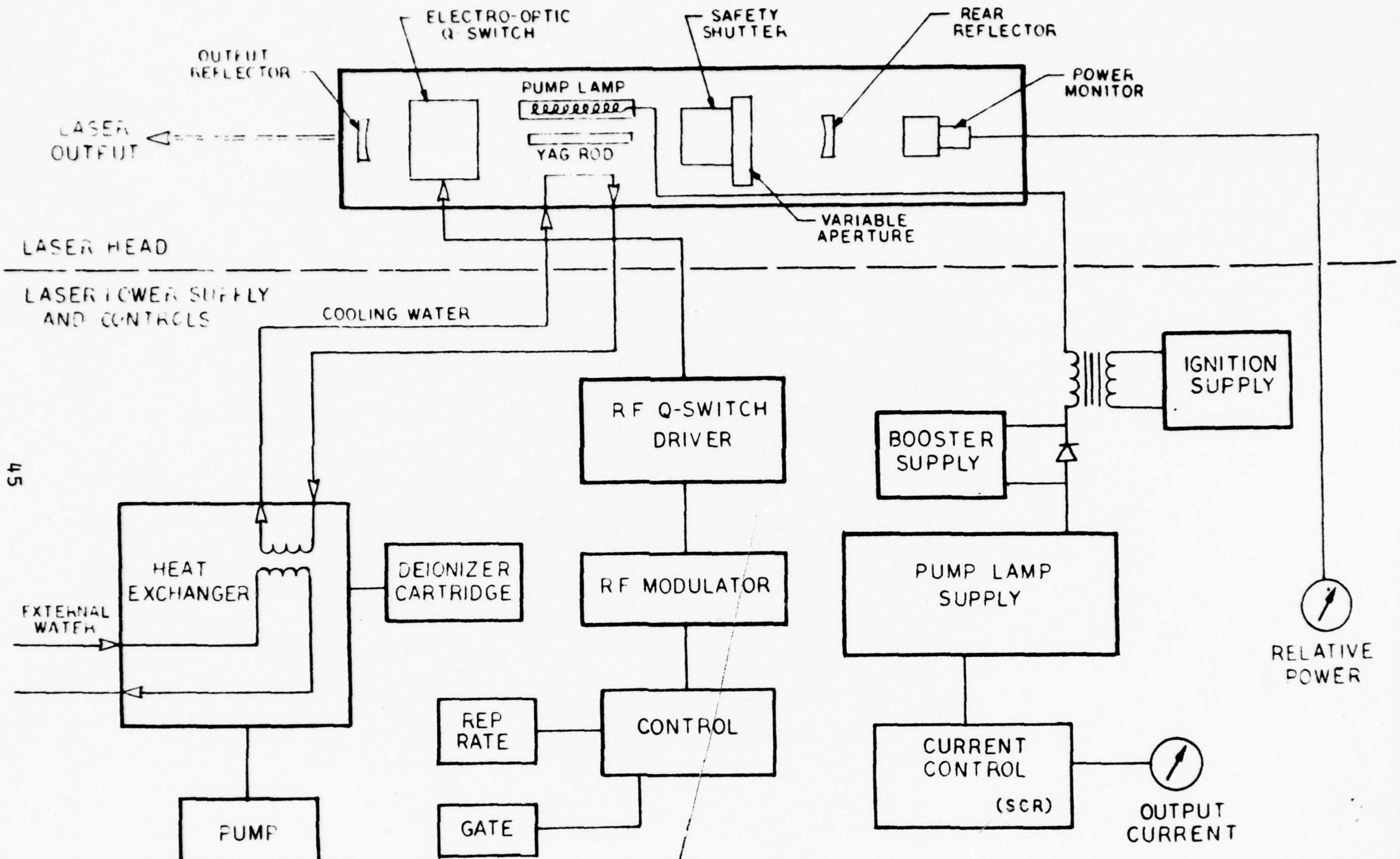
Specifications

CW Power Output	30 watts, multimode 4 watts, TEMoo
Peak Power Output	3 KW TEMoo from 1KHz to 6.5KHz 2 KW TEMoo from 6.5KHz to 10KHz
Average Power Output	2.5 watts at 5KHz, TEMoo 3.5 watts at 15KHz, TEMoo
Mode Selection	Integral iris diaphram
Cooling	Integral water-to-water heat exchanger
Safety Interlocks	High/low water pressure High/low temperature
Monitor	Integral elapsed time meter for pump lamp



LASER TRIMMER
BLOCK DIAGRAM

FIG. 2-3



LASER
BLOCK DIAGRAM

FIG 2-4

Prime Power	208/220V, single phase, 60Hz, 25 amps
Water Requirements	3 gallons per minute max, 90 gallons per hour average flow, 75°F max temperature

Optical Subsystem Description

General Description

The optical subsystem consists of the optics enclosure which contains the beam expanding telescope, the trinocular head, the illuminator, the TV camera, and TV monitor. Figure 2-5 depicts the optical train. The circuit to be trimmed may be viewed through the binocular eye-piece or on the TV monitor. Laser spot size selection is provided by adjusting the iris and spot size knob on the control panel of the optics box.

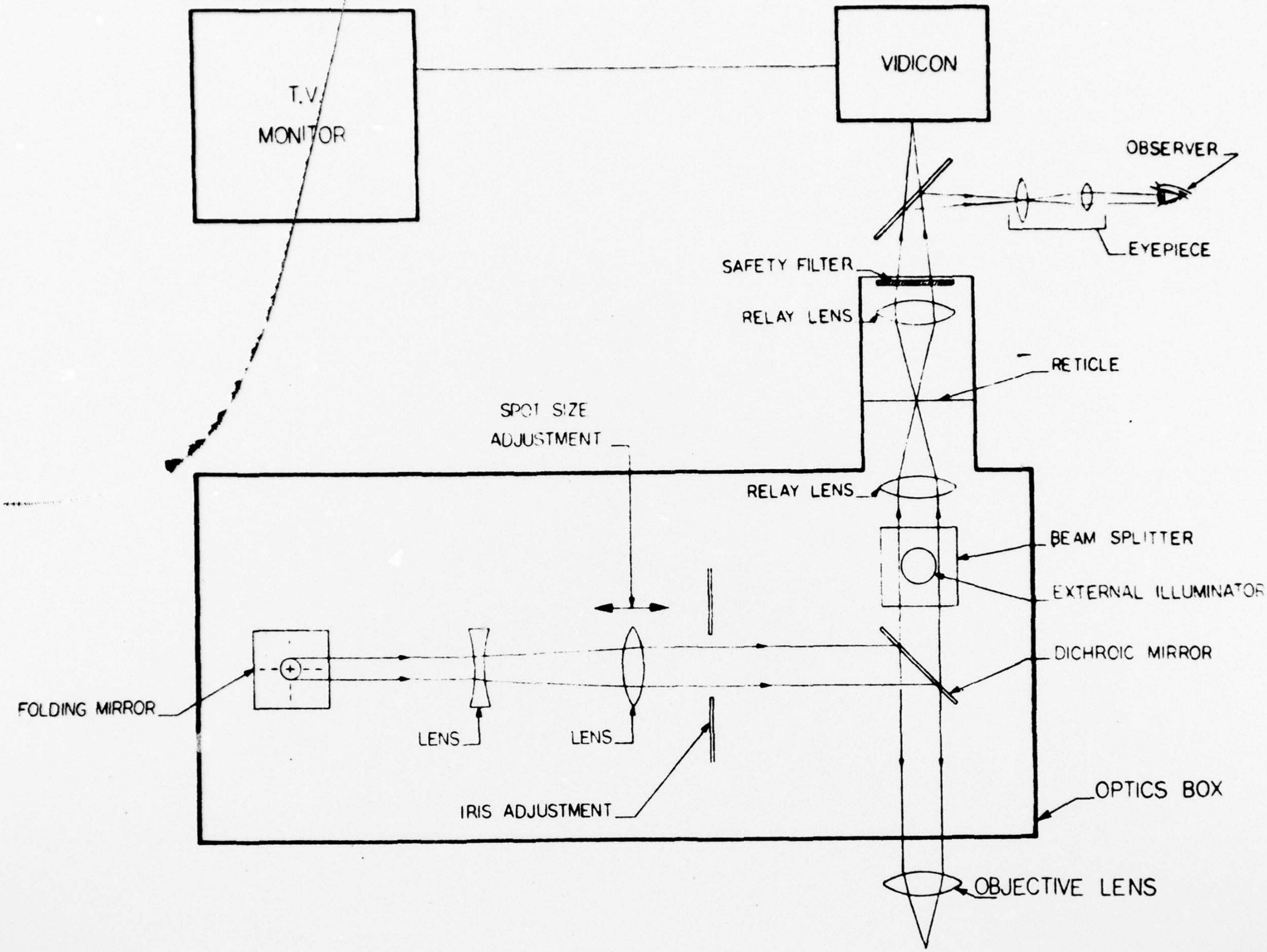
Specifications

Spot size adjustment	From 0.001 inch to 0.005 inch with 2-inch objective lens
Controls:	
Illuminator intensity	Controls illumination of work
Iris	Controls diameter of exit beam
Spot Size	Control divergence of exit beam
TV Camera	2/3-inch vidicon
TV Monitor	9-inch CRT

Beam Positioner Description

General Description

A modified beam positioner is used in this system, designated the Model 708S. It is a digitally-encoded, servo driven beam positioner, capable of receiving and storing position commands from the computer output. It then generates the necessary velocity commands to a servo positioning system to cause the beam to assume the programmed position. Three modes of operation are capable of being selected; two automatic and one manual. In the automatic slew mode, commanded by computer control, the X-Y positioner slews at a rate of 5 inches/second to the position being addressed, moving simultaneously in the X and Y direction with an acceleration and deceleration program resulting in minimum



OPTICAL SUBSYSTEM SCHEMATIC

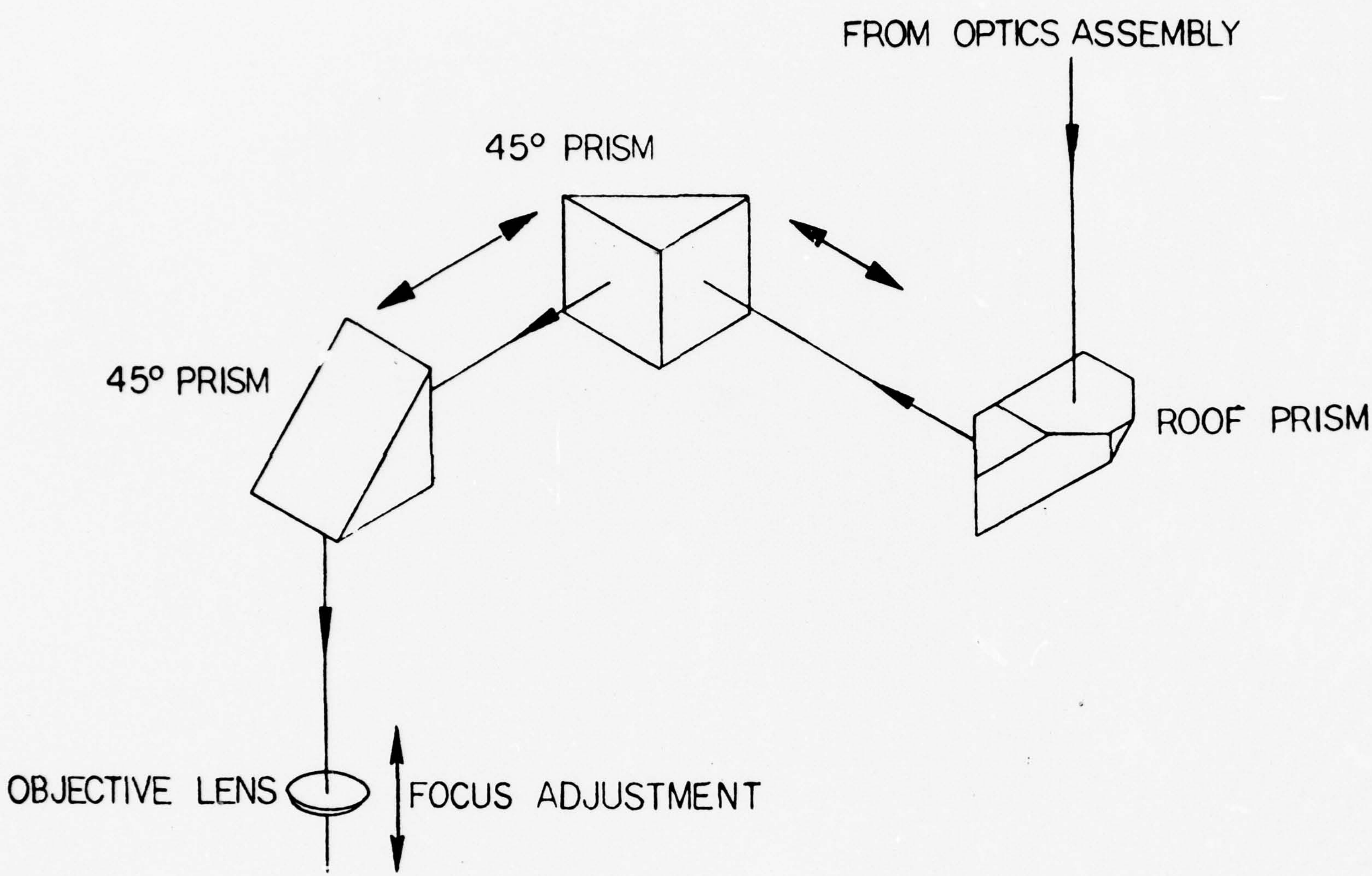
FIG. 2-5

positioning time consistent with a positioning accuracy of ±1/2 of the least significant bit. In the automatic trim mode, the beam positioner moves at an adjustable steady state rate of up to 400 mils/second, the motion being confined to either axis. Acceleration and deceleration rates are consistent with minimum trim times making use of synchronous laser triggering to provide a uniform density of laser energy/unit length of trim cut. In the manual mode, the computer interface no longer controls the beam position or laser triggering. Control is transferred by means of a front panel key switch to a two-axis joystick providing proportional velocity control in the desired directions. Laser triggering is either synchronous or asynchronous as selected from the laser front panel. The computer interface also supplies status monitoring signals to the computer including the two position encoder outputs and systems data outputs from the laser and the control system.

The optical path followed by the laser beam is illustrated in Figure 2-6. Figure 2-7 is a functional block diagram of the beam positioner electronics. The principal functions of the servo drawer and interface drawer are shown in block diagrams, Figures 2-8 and 2-9, respectively.

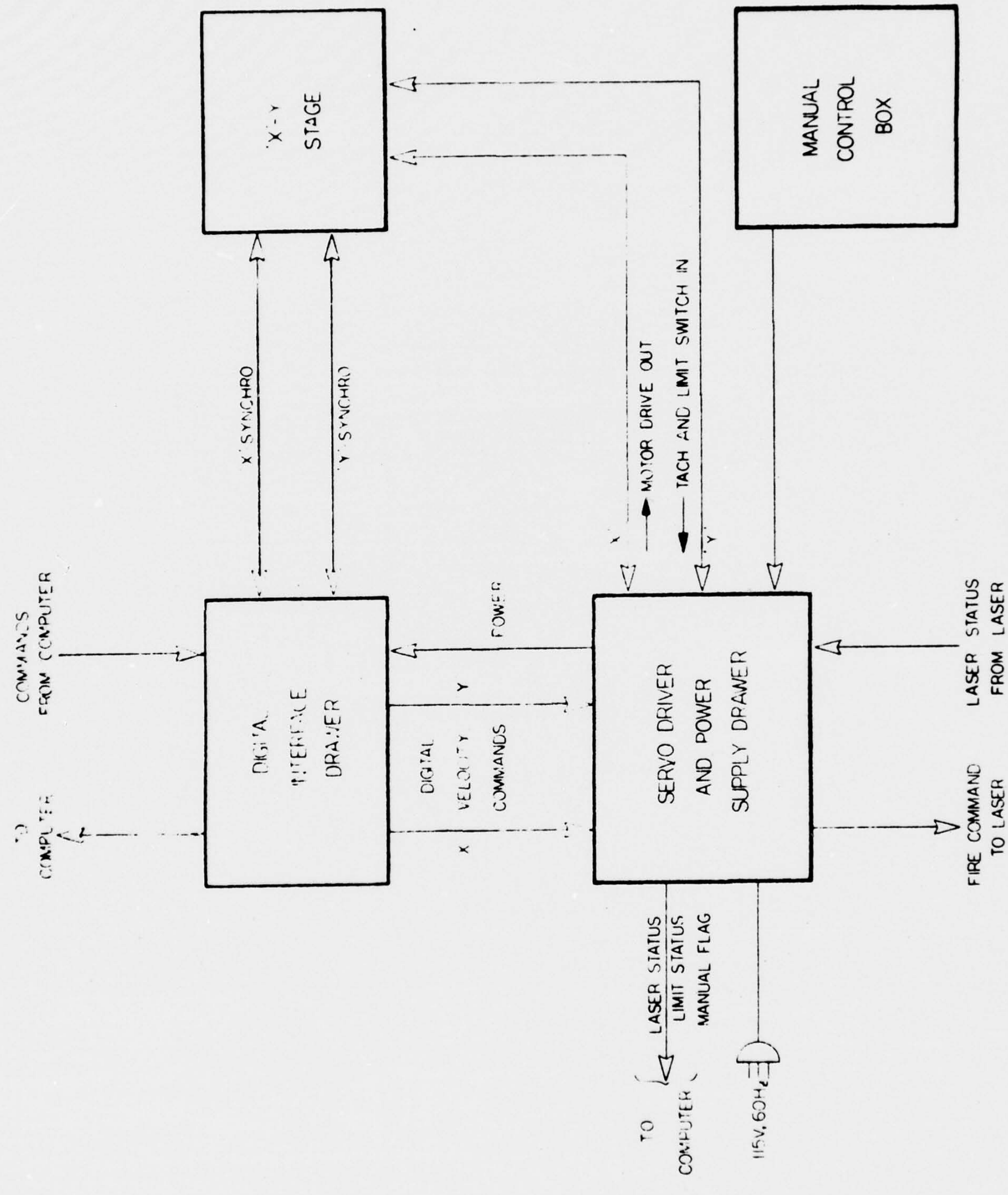
General Specifications

Positioning Range	2.0 inches x 2.0 inches
Positioning Accuracy	±0.25 mils
Positioning Rate - Slew	5"/second in both axis for positioning moves greater than or equal to 125 mils. For moves less than 125 mils, the rate decreases linearly with step length.
Trim Rate	0-400 mils/sec. adjustable for trims greater than or equal to 125 mils. For trim less than 125 mils the rate is proportional to trim length.
Stopping Distance During the Trim	0.5 mils following receipt of command
Laser Overlap	Under panel switch selectable at 25, 50, and 75%

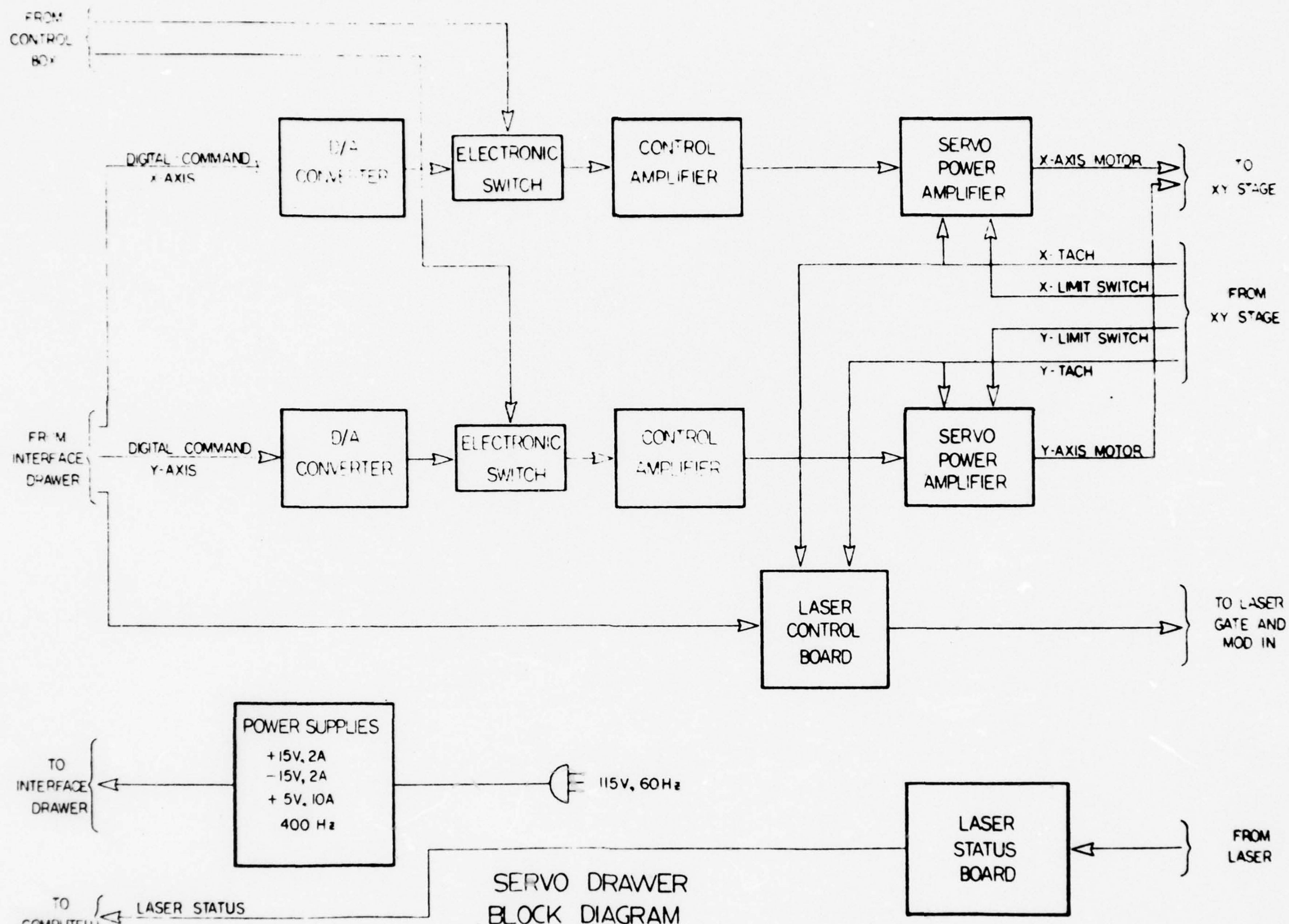


BEAM POSITIONER OPTICAL SCHEMATIC

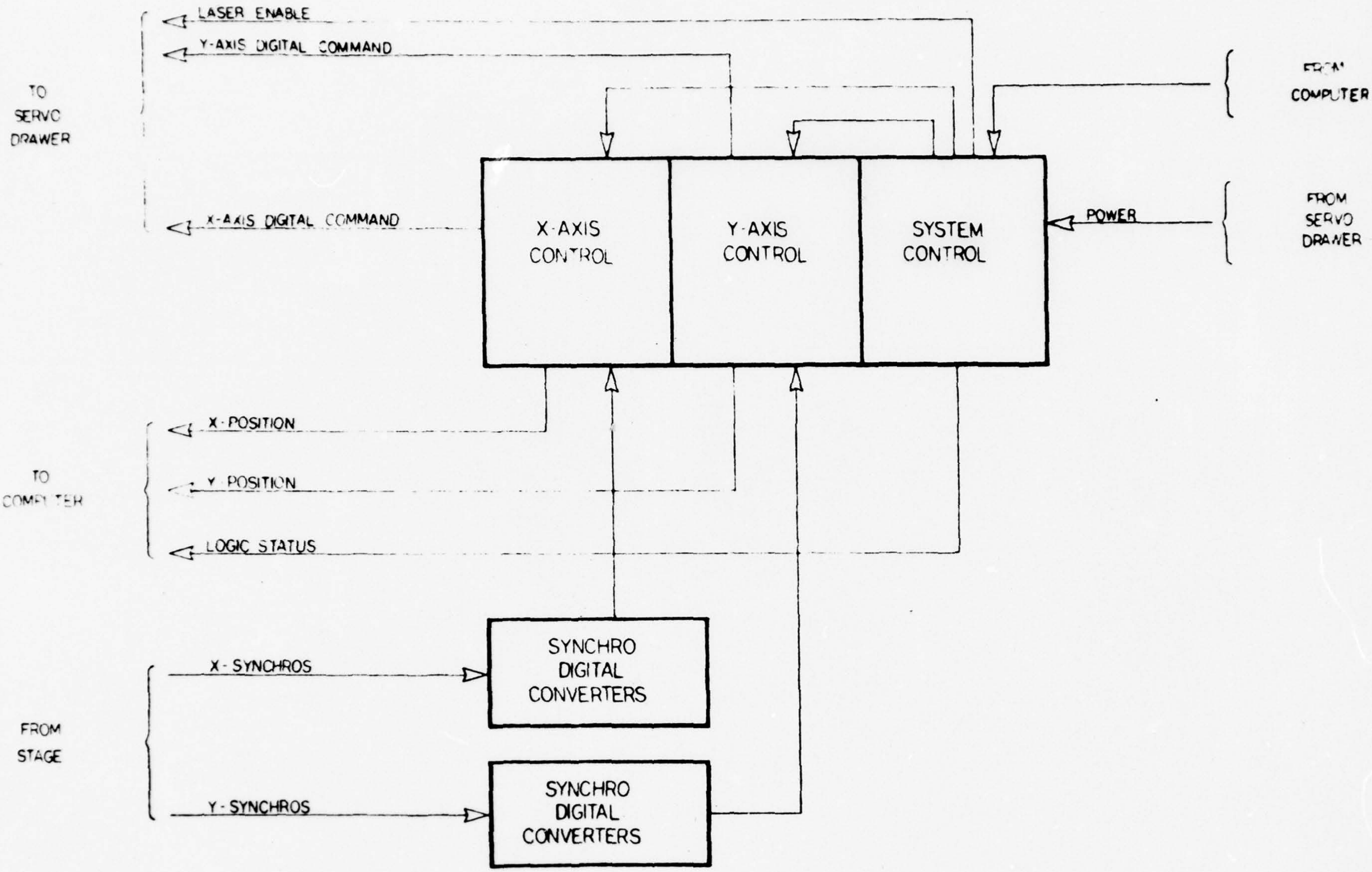
FIG. 2-6



BEAM POSITIONER
ELECTRICAL BLOCK DIAGRAM
FIG. 2-7



SERVO DRAWER
BLOCK DIAGRAM
FIG. 2-8



INTERFACE DRAWER
BLOCK DIAGRAM

FIG.2-9

Manual Operations	X-Y joystick controllable continuously from 0 to 5 inches/sec. switch selectable single or two axis.
Input/Output Logic Convention	Control signals from computer, 25 mA current delivered into a 4N28 photo-isolator located in the 708 interface equals logic "1".
Outputs to the Computer	A logic "1" output consists of sinking 25 mA from a 15V source located in the computer.

Computer Command Protocol

The command words are designated by a 2-bit code appearing on Bits 15 and 14 and a positive going strobe appearing on Bit 13.

No data equals	bit 15→1; bit 14→1
An X command equals	bit 15→1; bit 14→0
A Y command equals	bit 15→0; bit 14→1
A control command equals	bit 15→0; bit 14→0
25 mA equals	Logic "1" data to remain until the x ready status bit goes to zero.
Word 1	12-bit binary x positive, bits 1-12
Word 2	12-bit binary Y position same convention as Word 1.
Word 3	Bit 1 - Laser enable equals logic "1" Bit 2 - Laser inhibit equals logic "1" Bit 3 - Execute equals logic "1" Bit 4 - Trim equals logic "1" Bit 5 - Home equals logic "1" Bit 6 - Trim complete equals logic "1"

Computer Command Description

Binary X-Y position is measured from an origin located at the extreme left hand forward position of the beam. X position increases at the rate of 125/128 x 0.5 mils per least significant bit in the right hand direction facing the trimmer and Y position increases at the same

rate to the rear of the equipment. A laser enable command permits the laser to come on provided: 1) that the system is in the "trim" and not in the "slew" mode, and 2) that motion is taking place and that laser inhibit is zero. Laser inhibit absolutely inhibits the laser independent of all other commands. Execute must be in the one condition in order that the system move to a new address. Execute must go to zero and back to 1 before a new address can cause motion. Trim sets the beam positioner rate to the trim rate and permits the laser to go on provided it is not otherwise inhibited. Trim equals zero puts the system in the slew mode. Home in conjunction with an execute command, causes the beam to return to the X=0, Y=0 position. Trim complete stops the motion immediately upon its receipt if the system is in the trim mode. In the slew mode, it has no effect.

Status Signal Protocol

Bit 1	acknowledge
Bit 2	laser enabled
Bit 3	X ready
Bit 4	Y ready
Bit 5	Manual mode
Bit 6	Not (X minus) limit switch
Bit 7	Not (X plus) limit switch
Bit 8	Not (Y minus) limit switch
Bit 9	Not (Y plus) limit switch
Bit 10	Power on
Bit 11	Water flow OK
Bit 12	Water temperature OK
Bit 13	Water resistivity OK
Bit 14	All interlocks closed
Bit 15	Q-switch RF drive OK
Bit 16	Q-switch temperature OK
Bit 17	Laser power OK
Bit 18	Pump beam current OK
Word 2	12-bit X position, 12 straight binary bits with a data ready line
Word 3	12-bit Y position with data ready line

Status Signal Description

Acknowledge indicates that the control command has been received and may be removed from the input lines.

Laser enabled acknowledges a laser enable command.

X ready indicates that the previous X motion has been completed.

Y ready indicates that the previous Y motion has been completed.

Manual mode indicates that a key switch operated manual override is controlling the system.

The four (limit switch commands) Not (-)X, Not (+)X, Not (-)Y, Not (+)Y, indicate that the system is not inadvertently programmed against a stop and, hence, is incapable of moving. These signals will not normally be used unless the system is manually driven against a stop.

Beam positioner power is an indication that all power supplies required for running the servos are up to voltage.

Water flow OK is a monitor on the flow interlock in the laser.

Water temperature OK is a monitor on the water temperature interlock in the laser.

Water resistivity OK is a monitor of the water conductivity indicating incipient firing difficulties.

All interlocks closed - safety interlocks are closed and the safety shutter is not in place.

Q-switch RF drive OK is derived from the Q-switch driver voltage circuitry.

Q-switch RF drive OK is derived from the Q-switch driver voltage circuitry.

Q-switch temperature OK is a monitor on the Q-switch temperature interlock.

Laser power OK indicates the power exceeding a pre-set threshold as monitored from the relative power meter.

Pump lamp current OK indicates that the pump lamp current is between pre-set limits.

the 12-bit X position and Y position bits will be considered valid only when the X ready and Y ready signals are "1" respectively.

Data ready strobe will be a 100 microsecond minimum duration, "1" state.

2.1 M732 FUZE DESCRIPTION

Fuze operation is described under idealized conditions, (refer to Figure 2-10) by considering an artillery round impinging upon a target at an angle (θ) degrees, height (h) and traveling at a velocity (v) mph. The fuze is activated initially by a timing circuit (not shown) that was previously set by the gunner to actuate at some time prior to impact. The fuze is emitting rf CW energy roughly omnidirectionally so that the ground is illuminated continuously as altitude (h) decreases.

The oscillator (see Figure 2-11) serves as the CW transmitter, antenna, and receiver. The receiver is a simple diode connected across the transmitter/antenna combination.

A portion of the total transmit voltage (E_t) and receiver voltage (E_r) induced in the antenna appears across the diode terminals ($e_d(t) = E_t(t) + E_r(t)$; where e_d, E_t, and E_r and all phasors). The diodes and associated circuitry serve as a peak rf detector, producing an output voltage ($e_{sens}(t)$) proportional to $|e_d(t)|$. Since the shell velocity (v) is relatively high, $e_{sens}(t)$ is an audio signal at doppler frequency which increases in amplitude as altitude (h) approaches zero. Equation (1) describes this waveform as a function of time.

$$e_{sens}(t) = \frac{E_{max}}{(A - Bt)} \cos (W_d t + \emptyset_d) \qquad (1)$$

where E_{max}, A, B = Constants determined by the fuze output power, Initial altitude (ho), v, θ and rf reflectivity of the ground.

W_d = doppler frequency = $f(v, \theta)$

θ_d = arbitrary phase relative to $E_t(t)$

$e_{sens}(t)$ = oscillator detected output voltage. The rums level expected a h = H ft (desired detonation height) is called oscillator sensitivity.

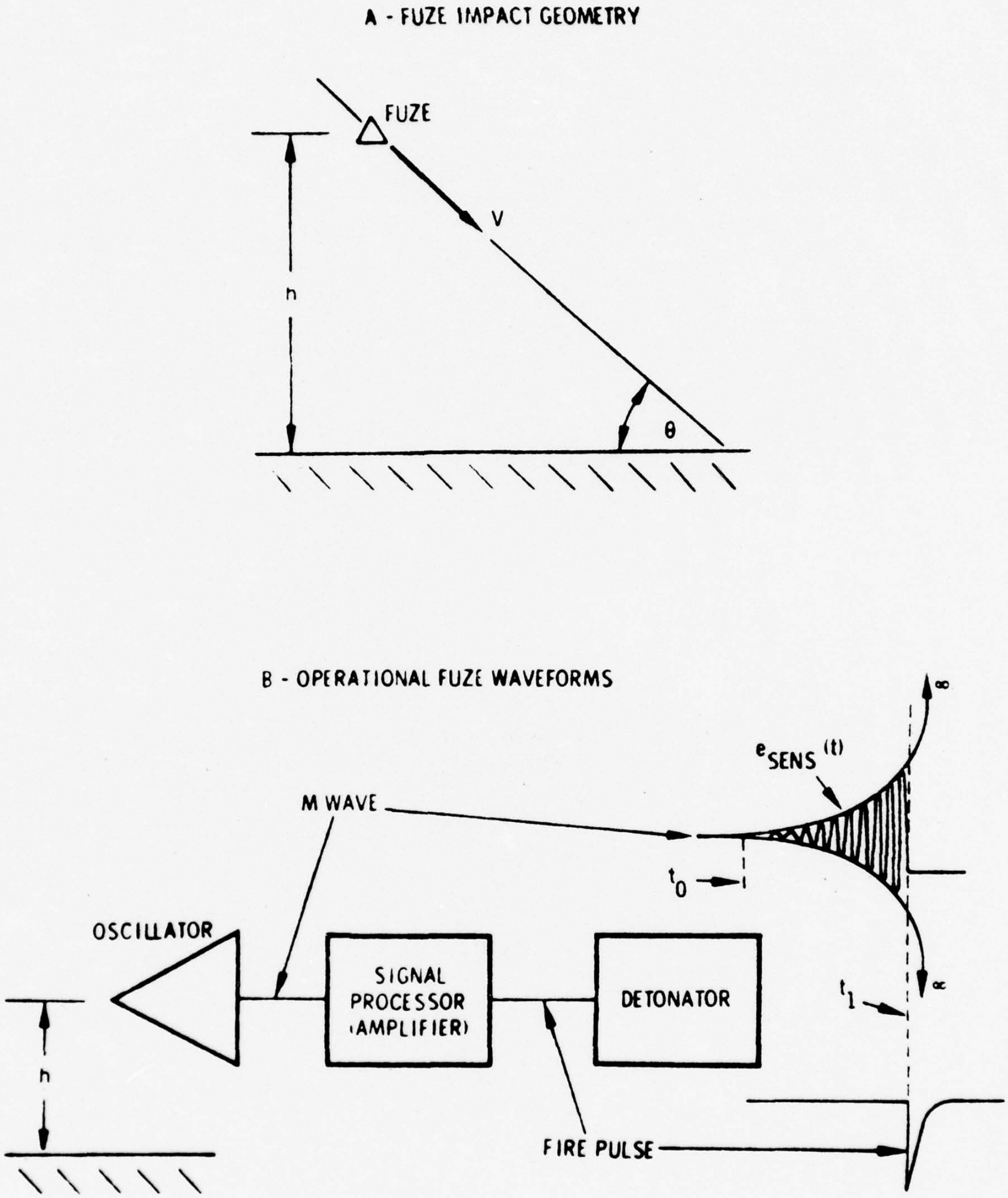


Figure 2-10. Fuze Operation

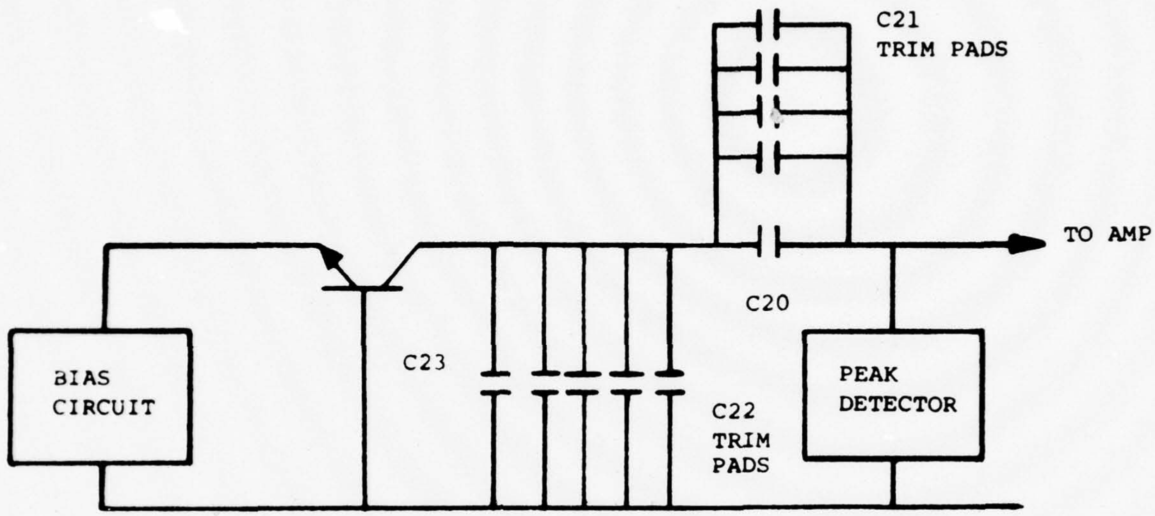


Figure 2-11. Oscillator, Simplified Schematic

Table 1. Boundary Conditions for Equation (1)

Time (t)	Altitude (h)	Comment
$t_0 = 0$	h_0	---
t_1	h_1	fire pulse out
$t_2 = \frac{A}{B}$	0	impact

Note that $t \rightarrow t_2$; $e_{sens}(t) \rightarrow \infty$, which is obviously incorrect. Equation (1) is, therefore, applicable for distances where $t<t_2$ and is presented to indicate the general amplitude variation with time (or distance to the ground).

Figure 2-10B shows the M-wave (i.e., $e_{sens}(t)$) after detection at the oscillator and at the amplifier outputs of the M732 fuze. The amplifier accepts an M-wave and provides a fire pulse at its output after an appropriate time. The time is determined by signal level, oscillator/amplifier overall gain, and amplifier SCR gate firing voltage.

Firing 2-12 shows the individual stages of the M732 fuze amplifier. Critical points are labelled and waveforms presented in Figure 2-13 corresponding to a typical M-wave input. Height of burst (HOB) is the critical figure of merit in a proximity fuze and is the quantity to be calculated utilizing FFT techniques. Variation in HOB depends upon many quantities within the individual fuzes. Analysis of the waveforms in Figure 1-13 and the circuitry of Figure 2-12 reveals some of the major causes in HOB variation from fuze to fuze, which are:

- Amplifier overall gain
- Oscillator sensitivity
- SCR gate firing voltage
- Amplifier frequency response

Since relatively inexpensive components with wide tolerances are used within the oscillator and amplifier sections of the M732 fuze, adjustment of amplifier gain and oscillator sensitivity are essential to provide specified performance. Present techniques provide for adjustment of two basic parameters: amplifier HOB, and oscillator sensitivity. Previous amplifier HOB testing used three M-waves in the time domain. These tests are lengthy, making it impossible to attain the 3,000 fuzes/hour rate required by the contract.

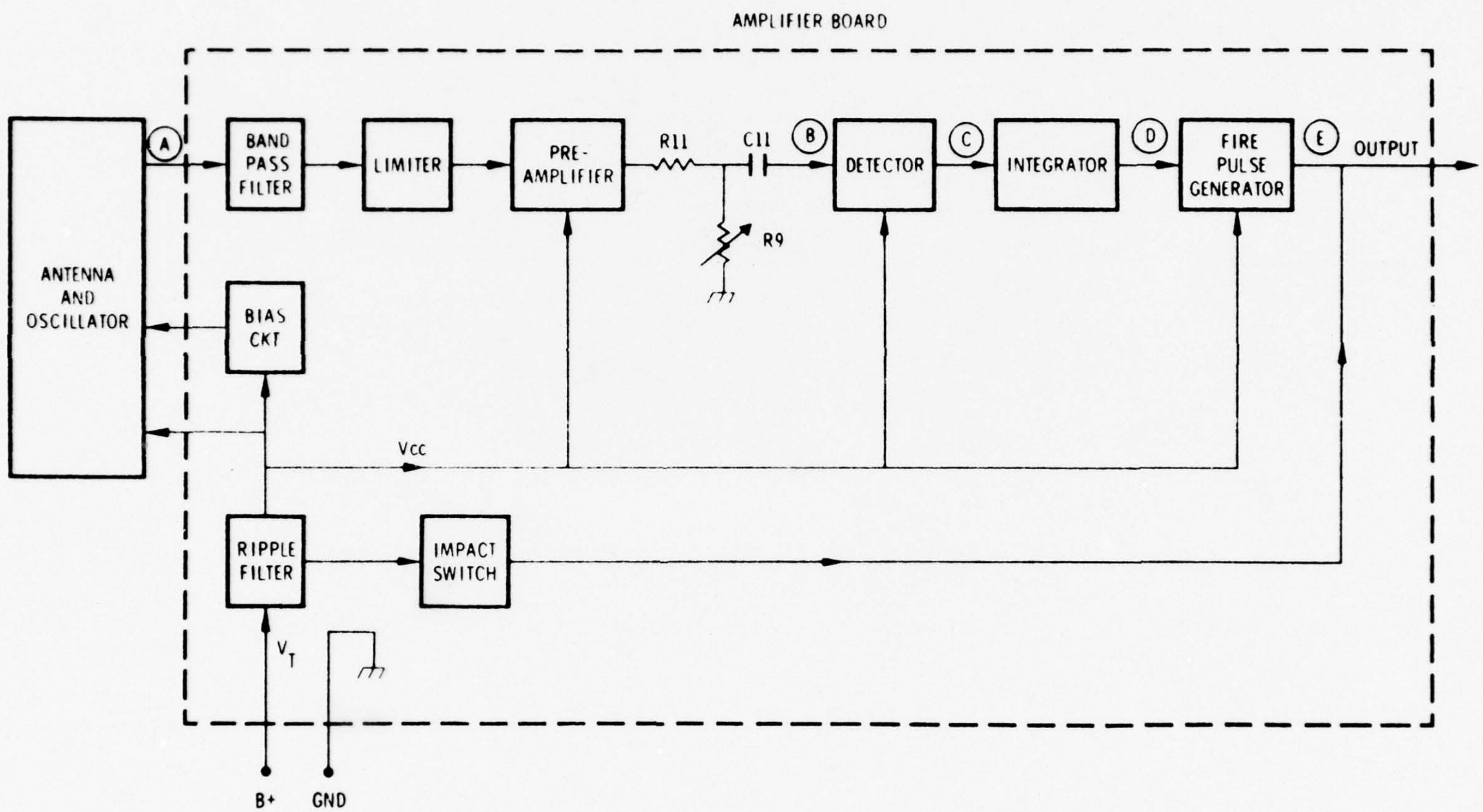


Figure 2-12. Fuze Amplifier, Block Diagram

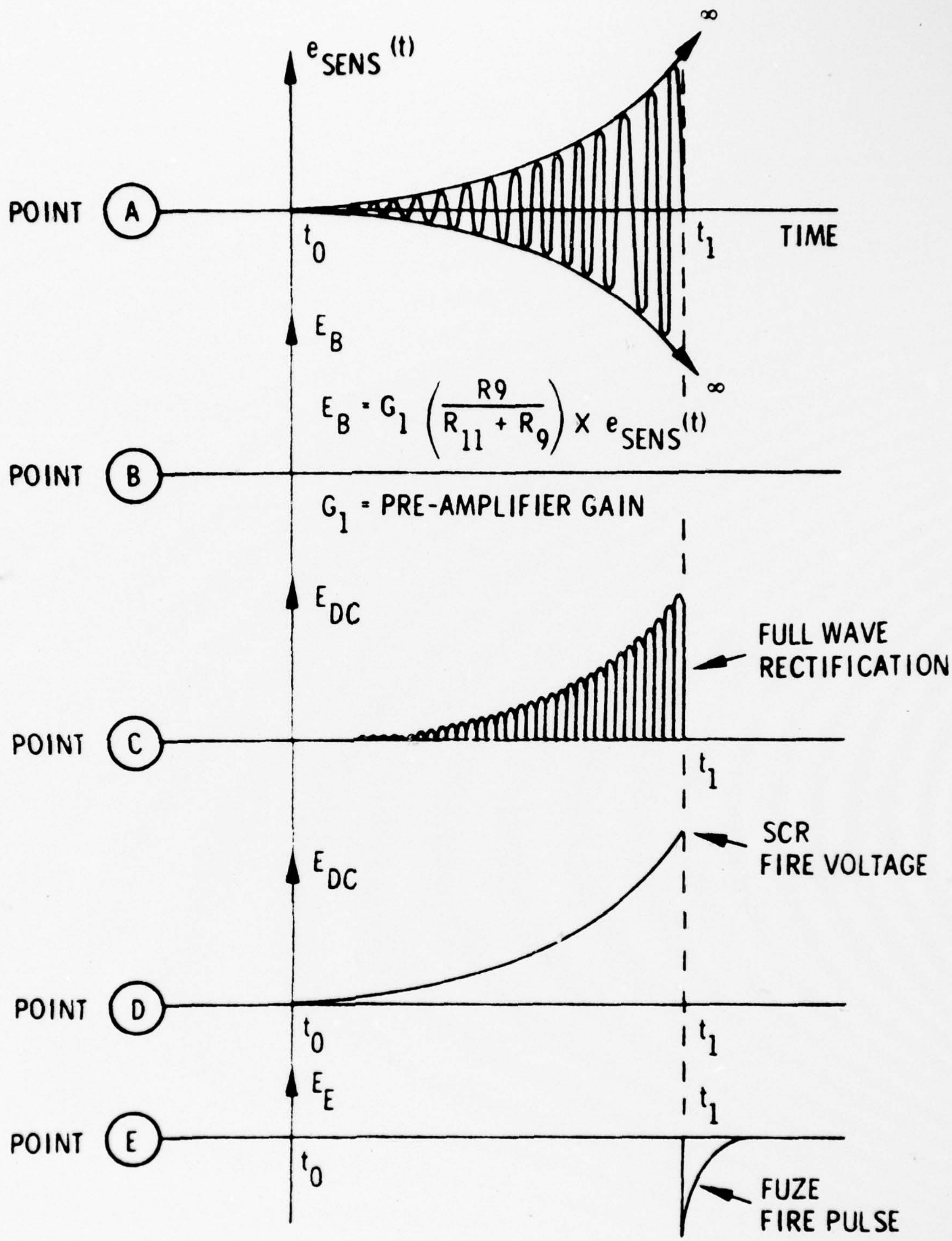


Figure 2-13. Fuze Signal Waveforms

2.2 AMPLIFIER MODEL

A mathematical model of the amplifier has been determined. This model will be used for the test and trim determination. The model is similar to previous models, except that the differential amplifier/detector is more completely described. An analysis of the circuit diagram and an experimental verification led to the block diagram shown in Figure 2-14. The differential amplifier/detector consists of two halves; one half responds to positive signals, while the other half responds to negative signals. The first element in each half is represented by an ideal half-wave rectifier. The half-wave rectifier is followed by a threshold device, which only allows voltages exceeding the threshold to pass. This is followed by a current generator, whose output current is a linear function of the input voltage.

The two sides of the detector/amplifier are independent. Measurements on a number of units have shown that the thresholds and current generators for each side can be quite different. It is these thresholds, the difference between the sides, and the M-wave input that has complicated the problem of adjusting the height of burst within a 1.2-second interval.

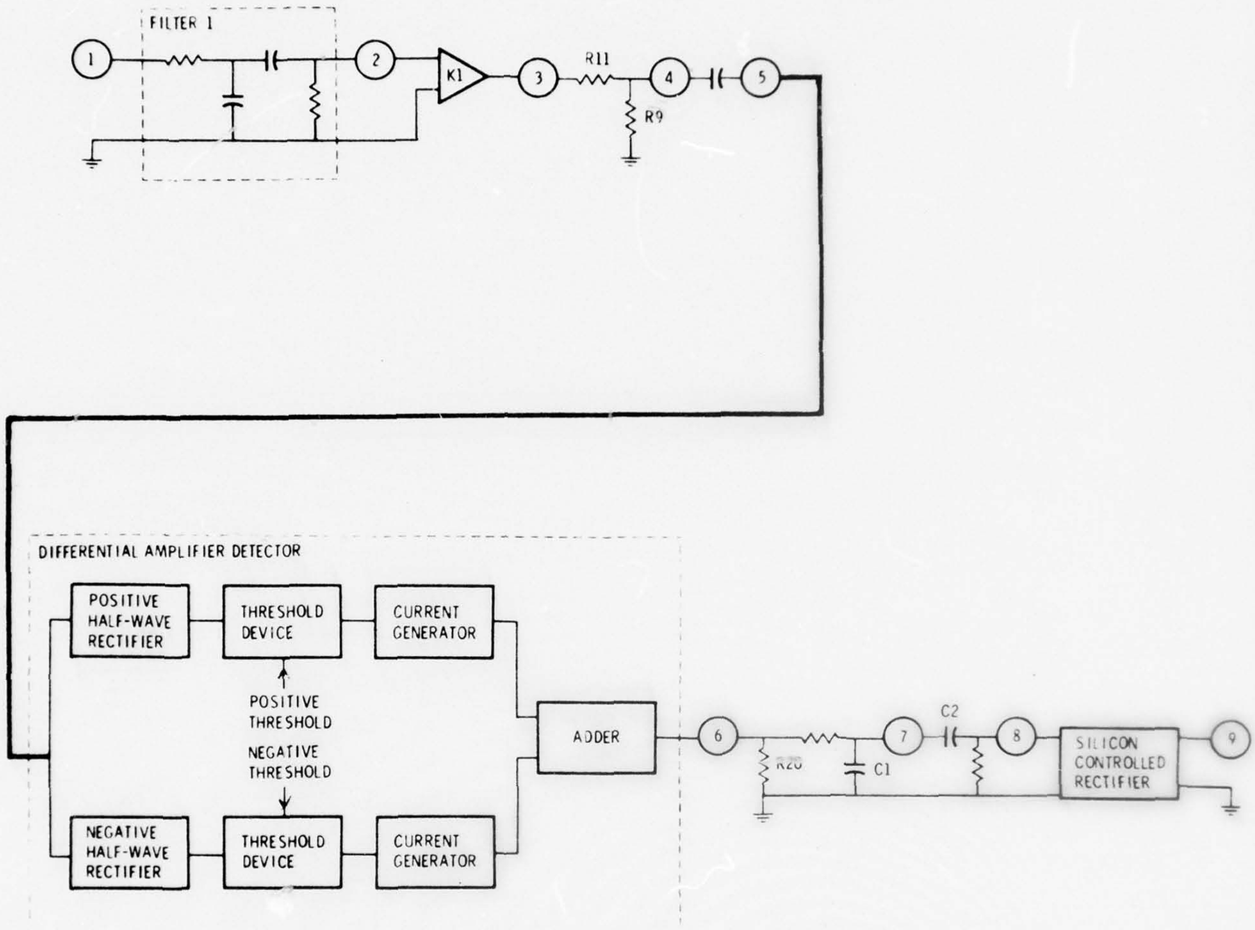


Figure 2-14. Amplifier Block Diagram.

2.3 AMPLIFIER TEST SIGNALS AND MEASUREMENTS

Because of the short time requirement (1.2 seconds) in which the height of burst of the amplifier is tested and adjusted, it is not possible to use an M-wave input. The M-wave lasts about 1.4 seconds and because of the nonlinear characteristics of the amplifier, would have to be applied at least three times to determine the amplifier parameters. Therefore, a series of short signals, which determine the amplifier characteristics, have been devised. Based on the measured response to these stimulus signals, the response to an M-wave is calculated, and the amplifier can then be trimmed to meet the height-of-burst requirement. The details of this operation constitute the specification for the real time amplifier test and trim process given in section 3.

3.0 REAL TIME TEST AND TRIM PROCESS REQUIREMENTS FOR THE M732 FUZE AMPLIFIER

3.1 INTRODUCTION

The real time amplifier test and trim process shal contain the following functions:

- Output a stimulus to the amplifier under test
- Measure the amplifier response to the stimulus
- Calculate the amplifier parameters of interest
- Determine the required gain correction
- Calculate the resistor trim requirements to obtain the gain correction
- Perform the resistor trim
- Log the pertinent data on the test for future reference

These functions are shown in figure 3-1. The initialization section accepts from the operator, the time of day, and information on the test. At this time, all flags and buffers are initialized, and the stimulus tables are read from the disk. At the start of test, the stimulus table is output to the amplifier. As will be described in a later section, there is a set of tables which must be outputted. In parallel with the stimulus output, the response of the amplifier to the stimulus must be measured. While the process of stimulation and measurement is progressing, the calculation of amplifier parameters must take place using data which has been accumulated. After all the amplifier parameters have been determined, a calculation to determine the required amplifier gain is performed. This calculated gain then represents a value which will cause the fuze to detonate at a specified height above the ground.

The trim requirements for the thick film resistor in the divider circuits are now calculated. These commands are then output to the laser subsystem in order to trim the resistor. After trimming is complete, a final check is made to verify that the gain is correct. Data logging of the amplifier parameters and execution time of each routine completes the process.

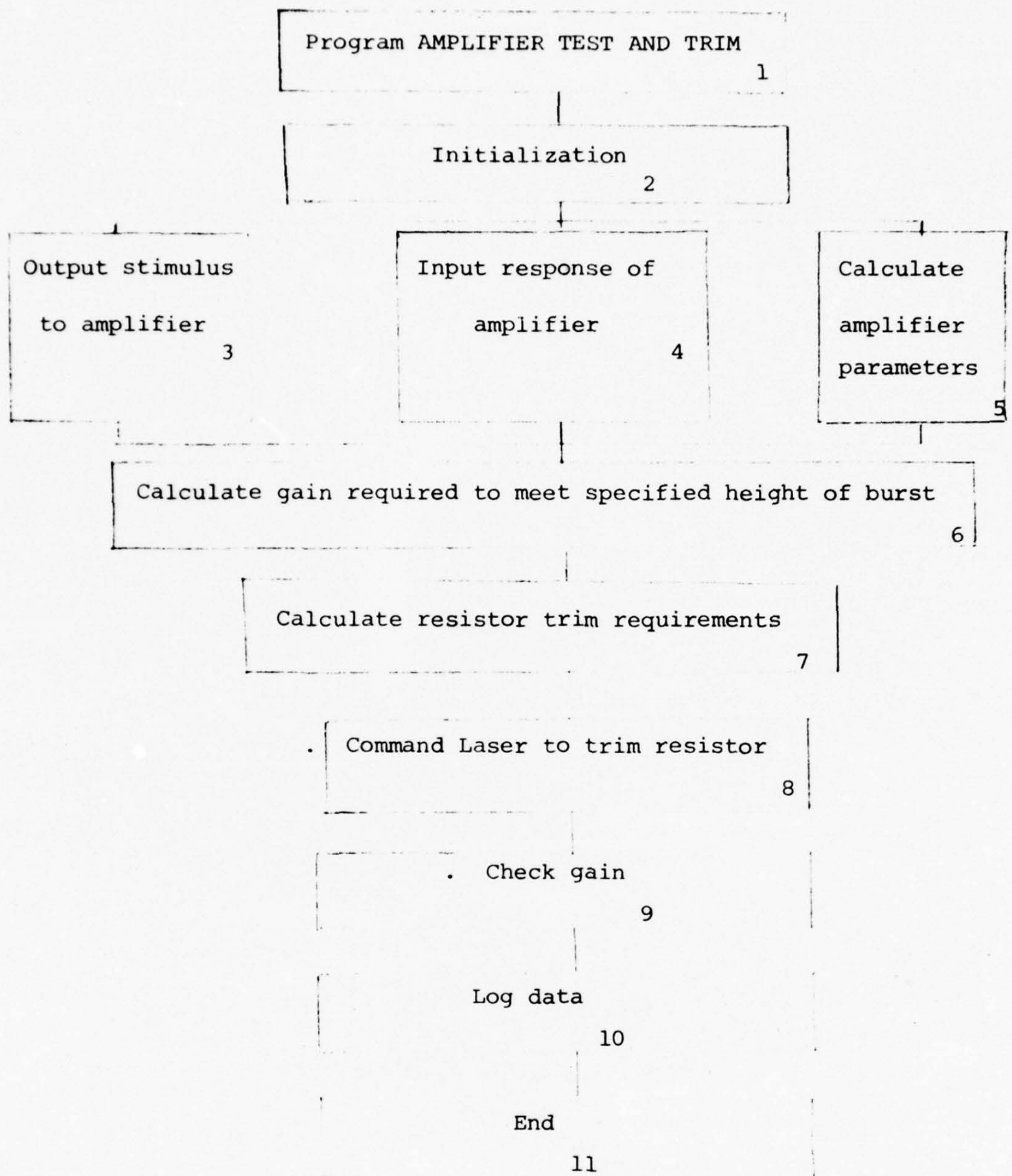


Figure 3-1. Functional Flow Chart of the Amplifier Test and Trim Process

3.2 INITIALIZATION

The initialization process consists of two functional parts (see figure 3-2). The first part "Test Set Up" is performed at the start of operations. Its purpose is to prepare the system to continuously run the amplifier test program for an indefinite succession of amplifier units. The functions performed are the following:

- Load amplifier test program
- Load stimulus table
- Energize amplifier test hardware
- Input time and date from the operator
- Input operator comments (up to 50 English words)
- Input last amplifier serial number from the operator
- Load and print summary of previous tests on request
- Run amplifier test process.

The amplifier test program itself has a local initialization function. It performs the following:

- Initialize flags, buffers, etc.
- Print "Ready" signal for the operator
- Wait for the "Go" command from the operator
- Read clock
- Read laser position

After receipt of the "GO" command, the amplifier test and trim process will automatically continue until the unit is completely tested, and the data is logged.

Test Set Up

- Load amplifier test program
- Load stimulus table
- Energize amplifier test hardware
- Input time and date
- Input operator comments (up to 50 English words)
- Input last amplifier serial number
- Load and print summary of previous tests if requested
- Run amplifier test program

Initialization

- Clear flags, buffers, etc.
- Print "Ready" signal
- Wait for a "Go" command from the operator
- Read clock
- Read laser position
- Start test and trim process

Figure 3-2

3.3 Input/Output Process

The funtion of the input/output process is to configure the hardware for each test, provide stimuli to energize the amplifier, and take sample measurements of the amplifier response.

For reference, figure 2-14 contains a block diagram of the mathematical model of the amplifier and a description of the unit is given in section 2. Table 3-1 summarizes the hardware configuration, input signals to the amplifier, measured voltages for each test, and the amplifier parameters whose values must be calculated.

In order to achieve minimum execution time it is necessary to have parallel operation of applying the stimulus, measuring the amplifier response, and calculating the amplifier parameters. Figure 3-3 indicates the functional flow required to obtain this operation.

The measurement control function (Figure 3-3a) is a continuation of the initialization process. The initial block in the control process is to energize the I/O process. The I/O module (Figure 3.3.b) must first update the information on which I/O test is to be performed. On initialization from the control process it will record a one. The routine to perform test 1, will configure the hardware for this test. (Details are given later). It then initiates a read function through a DMA channel. After initiation of the I/O process (which will not be the completion of the actual stimulus output and measured response input) the system returns to measurement control. Completion of the I/O process shall bring control back to the I/O function. The measurement number is then updated to 2. The hardware is configured for the second amplifier measurement and an input (DMA) read is ordered. After initiation of a read it is required that the stimulus be applied to the amplifier within several milliseconds. Note that the system was ordered with the capability to have an output immediately after initiating an input. The correct timing of I/O will automatically be achieved providing the I/O is made through DMA channels.

Table 3-1. Measured Amplifier Characteristics

	Measurement Objectives	Hardware Conditions	Input Signal	Measured Voltages	Amplifier Parameters
1.	DC attenuation of divider	Short C1,C2; parallel R20 by a 100Ω resistance	DC voltage from fuze amplifier	V3, V4	Divider attenuation
2.	Gain to point 5	Short C1,C2; Parallel R20 by a 100Ω resistance	CW	V5	Rectified average of ac
3.4	Positive and negative threshold and current generator	Short C1,C2; parallel R20 by a 100Ω resistance	Delayed positive and negative ramps at V6	V5, V6	Least mean square fit to line to give thresholds and current generators
5.	Filter step response	Remove short from C1, C2, and R from accross R20	Step of carrier	V8	Preliminary calculation of step input to filter A, p1, p2 of u(t), and C and D of h(t)
6.	*SCR firing* voltage	Remove short from C1, C2 and R from accross R20	Increase carrier step to maximum	V8	Spike determination at SCR gate

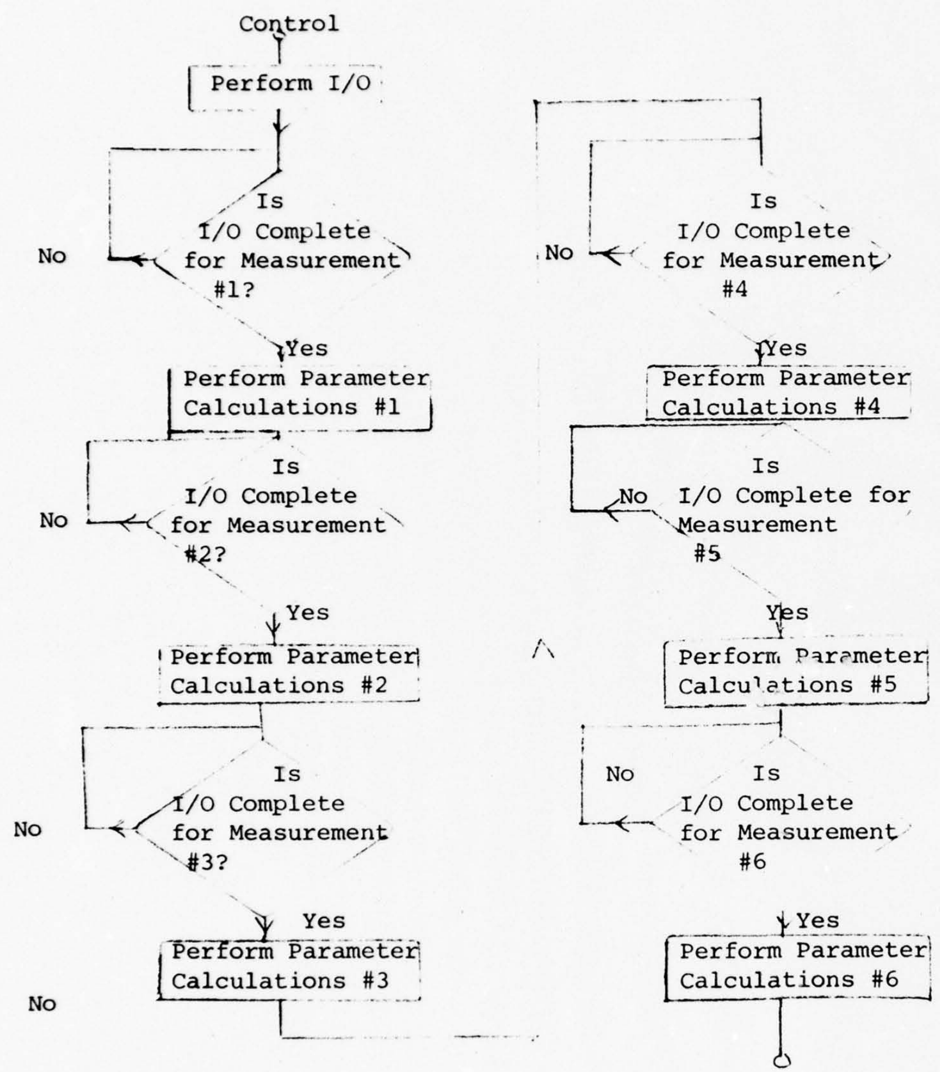


Fig. 3.3a Measurement Control
Test System Control Functional Flow

Initial Entry from Control. Succeeding entries after a Channel I/O Complete

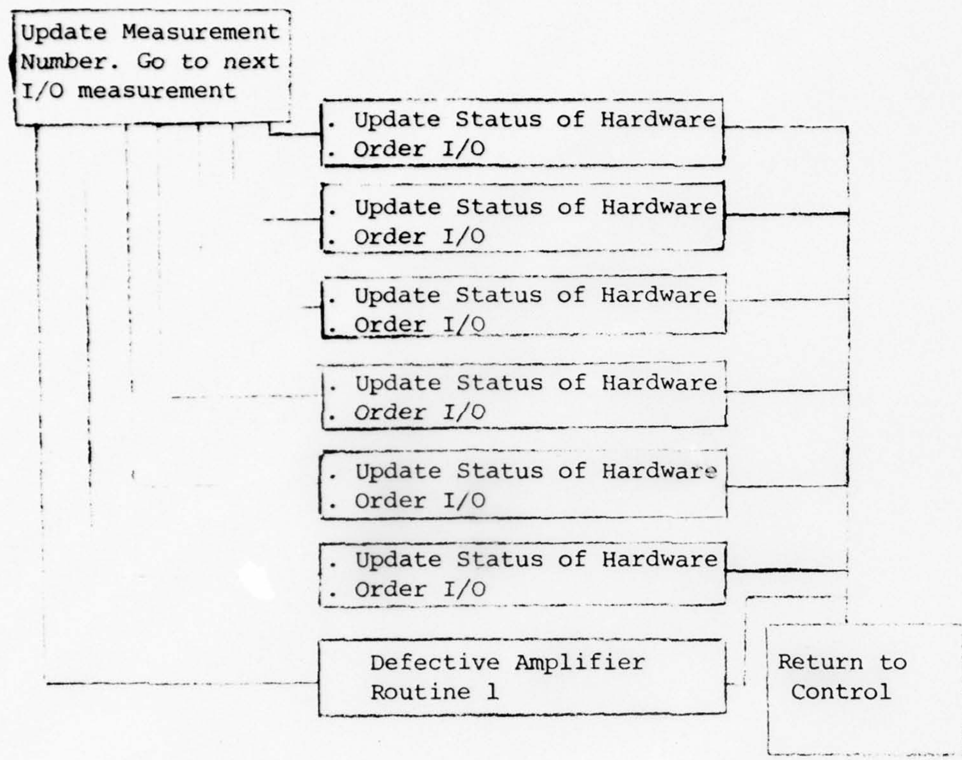


Fig. 3.3b. I/O Functional Flow

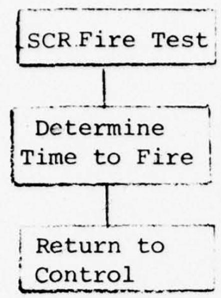


Fig. 3.3c. Event Sense Functional Flow

Completion of the initiating of I/O for measurement 2 returns control to the calculations that were in process at the time when interrupt occurred. At this point, the I/O for the measurement is complete. Calculation of the first set of parameters can be started. Details on the parameter calculations are given later. These calculations may or may not be completed, when an interrupt occurs at the end of the measurement 2 I/O. If this is the case, the interrupt shall cause control of the system back to the I/O module. The measurement number is then updated to 3; the I/O is initiated for measurement 3; and control returns to complete the interrupt calculation, This process continues until all six measurements are complete and all six parameter calculations are carried out.

In summary, it is emphasized that the I/O process must be continous. As soon as the I/O for one measurement is complete, the I/O for the next must be initiated. Calculations of the amplifier parameters must be made in parallel with I/O. The only limitation on parallel calculation is that the calculation must wait until all the data is present. The more sophisticated approach of using partial data to start the parallel calculations will not be employed for this test.

3.4 I/O MEASUREMENT/STIMULUS PROCESS

The functional organization of the I/O measurement/stimulus process was described in the previous section. A functional flow chart was given and discussed. (fig. 3-3). The I/O functions will now be considered in detail.

The first function in the work flow consists of an update of the measurement number and will not be considered further. The measurements themselves are now discussed in detail. The measurement process must control both the relay closures and the positions of the analog multiplexer to be able to read data. The relay functions and the connections to the analog multiplexer are given in tables 3-2 and 3-3 respectively.

The functional flow of the measurement routines are shown in figures 3.4 to 3.9. They are all similar to each other. Consider first figure 3.4, the flow of the DC attenuation measurement. The first step is to deenergize all relays. This, in effect, is an "all clear" signal which readies the hardware for any of the tests. The next step is to energize relay 1. Energizing this relay in turn energizes other relays in the external hardware which sets up the first conditions in step 1 of table 3-2; i.e. capacitors 1 and 2 are shorted and R20 is paralleled by a 100 ohm precision resistor.

The energizing of relay 1 is followed by a five millisecond wait to ensure that all the hardware has reached the final state. Now, the pacer in analog controller 1 is set to 45,000 words/sec. This will cause an ensuing read to progress at this rate. After the pacer is set, the analog multiplexer is set to read positions 2 to 3. The data on these positions, voltages V3 and V4 of the amplifier, will then be sampled by a read command. Lastly, a two word read is actually ordered. The program then returns to control while the actual read takes place. It is again emphasized that the read commands must be such that the actual process of reading takes place in parallel with program execution.

Table 3-2

Relay Functions

Relay No.	Function
1	D.C. Attenuation Test
2	Preamp Gain
3	Pos. & Neg. Thresh. and Current Gain
4	Not assigned
5	Not assigned
6	SCR Firing Voltage
7	Fast Reset
8	Not Assigned
9	Not Assigned
10	Fast Amplifier Charge
11	Amplifier BITE
12	Oscillator BITE

Table 3-3

Analog Multiplexer Connections

Analog Multiplexer Position	Connection
1	Amplifier Input
2	Voltage Point 3 of amplifier
3	Voltage Point 4 of amplifier
4	Voltage point 5 of amplifier
5	Voltage point 8 of amplifier

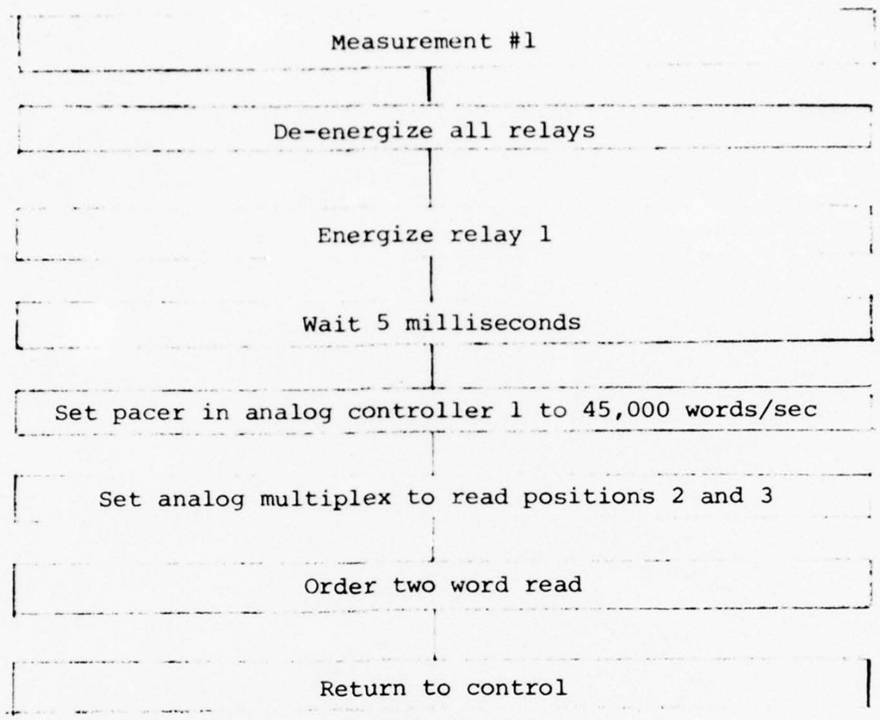


Figure 3-4. Functional Flow of Measurement 1

The functional flow of the second measurement is given in figure 3.5. The hardware configuration is identical to the previous routine (the relays will not have to be reset). Initially set the pacer in analog controller 1 to 45,000 words/sec; then set the pacer in analog controller 2 to 15,000 words per second. Both of these values represent the maximum capability of the D/A and the A/D respectively. Next, the analog multiplexer is set to read position 4. Position 1, namely, the input to the amplifier, is not used since the computer will output a known, predetermined signal. In order to provide proper "roll over" of the analog multiplexer, the last address detector must be initialized. The actual output/input commands can then be issued. For this test, a 200 word stimulus table representing ten complete cycles of a 720 Hz sine wave is output. The values in the table are equal to 100 $\sin(2\pi \times 720 \times n/15{,}000)$ where n is the table entry number initialized to zero.

In order to allow time for the amplifier transient to die down, the initiation of the output of the stimulus is followed by a 2 millisecond "wait" prior to the input of the amplifier response which will be issued for 500 words. The 500 words will represent eight cycles of amplifier response. Upon completion of this command sequence, system returns to control. Again, it must be emphasized that the output of a stimulus and the input of amplifier response must be such that output, input and calculation take place in parallel.

The functional flow of the third and fourth measurement is almost identical to the previous measurement flow (See figure 3.6). Again, the pacers in controllers 1 and 2 are set to 45,000 and 15,000 words/second respectively. The third and fourth measurements are virtually identical to each other. They differ only in the table which forms the stimulus signal. The third measurement is for data to calculate the amplifiers positive threshold and positive current gain while the fourth measurement is for data to calculate the corresponding negative parameters. The flow shown in figure 3.6 covers both routines. Since the hardware conditions are the same as the previous routines, there is no block in the flow chart to reset the interface relays.

Measurement 2

Set pacer in analog controller 1 to 45,000 words second

Set pacer in analog controller 2 to 15,000 words/sec.

Set analog multiplexer to read position 4

Initialize last address detector

Output table containing ten cycles of 720 Hz sinusoidal signal (200 words)

Wait 2 millisec

Read measurement data (500 words)

Return to control

Figure 3-5. Functional Flow of Measurement 2

Measurements 3 and 4

Set pacer in analog controller 1 to 45,000 words second

Set pacer in analog controller 2 to 15,000 words/second

Set analog multiplexer to read positions 5 and 6

Initialize last address detector

Output table containing linear ramp (200 words)

Read measurement data (120 words)

Return to control

Figure 3-6. Functional Flow of Measurements 3 and 4

The first block indicates setting the pacer in analog controller 1 and the second block the pacer in analog controller two. The analog multiplexer is then set to read positions five and six. Once this is done, the last address detector must be initialized to correspond to the analog multiplexer setting.

A table of 200 words is then output as the stimulus. The values entered into this table will be finalized after a simulation has been completed. At present, integer values ranging from zero to +1000 in equal steps will be used. Once the stimulus signal command is issued, the measurement must be enacted. 1,200 words will be read into the measurement table. These words are used for the calculation of the amplifier's positive threshold and positive current gain. As pointed out above, the functional flow of measurement 4 is the same as for measurement 3. They differ only in the stimulus described. Measurement 4 will use a stimulus which contains values that are the negative of the measurement 3 stimulus. The measured data, in this case, will be used to calculate the amplifier's negative threshold and negative gain.

Figure 3.7 is the functional flow for the fifth measurement. This test will obtain data to calculate the step response of the filter in the amplifier. Since this measurement does not require a specific hardware configuration all relays are de-energized. As previously indicated, this is an "all clear" signal to the hardware which puts all interface relays into the open state. Now the pacer in analog controller 1 is set to 15,000 words/second. The pacer in analog controller 2 is set to 5,000 words/second. (This data rate is considerably lower than the previous settings since the filter bandwidth is much lower than that of the amplifier). The analog multiplexer is set to read position 8, which is connected to the filter output. Input signals to the filter will be calculated from measurements already taken on previous tests of the amplifier. Hence no samples of the filter input will be taken.

After the analog multiplexer is set, the last address detector must be initialized, followed by a three millisecond wait to insure that all the relays have stablilzed. The measurement can then be initiated. In this case the measurement is initiated prior to applying the stimulus signal to insure that data is not lost. Once the measurement is initiated a 720 Hz modulated step stimulus signal will be applied by outputting a table of integer numbers equal to 100 $\sin(2\pi \times 720\, n/1500)$. There are 1,500 words in this table so that the stimulus duration is 0.1 sec.

Measurement 5

De-energize all interface relays

Set Pacer in analog controller 1 to 15,000 words/second

Set Pacer in analog controller 2 to 5,000 words/second

Set analog multiplexer to read position 8

Initialize last address detector

Wait 3 milliseconds

Read measurement data (4,500 words)

Output a 720 Hz modulated step (1500 words)

Return to control

Figure 3-7. Functional Flow of Measurement 5

The last of the measurements (i.e. no.6) is to obtain data on the firing voltage of the SCR. It differs from the previous measurements in that the process continues until either the SCR fires or 0.1 seconds have elapsed. The functional flow is shown in figure 3-8. The pacers are initially set. Then the event sense word in the event sense card is set to zero. The card is then set to the "difference" mode; i.e., the hardware checks if the internal words differs from the external word. The event sense is then actually energized.

The analog multiplexer is set to read position 8 (the filter output) and the last address detector is initialized. A measurement is started for 4,500 words. The system must record the time for test start from the internal computer clock. A stimulus table of 500 words is applied to the unit. The values in the table are equal to 600 sin (2π x 720 x n/5000) where n is initially zero.

When either a channel I/O complete or the appearance of a signal on the event sense card occurs, calculation of the SCR fire voltage can commence. If the channel I/O complete occurs, a defective amplifier is under test. The system then simply prints on the TTY that the amplifier is defective and that the SCR failed to fire (see figure 3.9). Control then goes to the data log module of the amplifier test program. If a signal occurs from the event sense card, it is an indication that the SCR has fired. The "SCR Fire" function is then executed (figure 3.10). Here the event sense signal is de-energized, and the time is read from the computer clock. This time and the previous time reading are differenced to determine the elapsed time for measurement 6. This, is followed by a calculation to determine the approximate point in the measurement table at which the firing voltage information is to be found. Specifically, the position is equal to 45,000 times the elapsed time. The fast amplifier charge relay (R10) is energized and the test information is then logged for future reference.

Measurement #6

Set pacer in analog controller 1 to 5,000 words/sec

Set pacer in analog controller 2 to 45,000 words/sec

Send an integer word whose value is zero to the event sense card

Set the event sense card to "difference" mode;
i.e. to test if internal and external words are different

Energize event sense so that a signal will occur if computer
and external words differ

Set analog multiplexer to read position 8

Initialize last address detector

Read measurement data (4,500 words)

Read Time

Apply a 720 Hz modulated step (500 words) stimulus

Figure 3-8. Functional flow of Measurement 6

Defective Amplifier Report

Print on TTY "Defective Amplifier" "SCR failed to fire"

log data of the test

Figure 3-9. Functional Flow of Defective Amplifier Report

SCR Fire Test

De-energize event sense interrupt

Determine time

Calculate elapsed time for measurement 6

Calculate approximate position in measurement table to reach the fire voltage

Energize Fast Amplifier Charge Relay (R10)

Return to Control

Figure 3-10. Functional Flow of SCR Fire Test

3.5 AMPLIFIER PARAMETER CALCULATIONS

The parameters of the fuze amplifier are calculated using the data recorded during the measurement of amplifier response to the applied stimuli. Again, it must be emphazed that these calculations shall take place in parallel with the I/O measurement process. The only exception to the calculation of amplifier parameters in this manner occurs when the data has not yet completely arrived. After each parameter calculation, a test is made on the measurement number set to determine if the data is completed for the next parameter measurement. If the data is not there, the program must wait for completion; if the data has arrived, the program proceeds with the parameter calculations.

Parameter Calculation (Measurement 1 data)

The first calculation determines the DC attenuation of the divider network. The DC attenuation is simply the voltage V4 divided by the voltage V3 as determined during measurement 1. This parameter is logged and will be used later to determine trim requirements.

Preamplifier Gain Calculation (Measurement 2 data)

The Preamp gain calculation consists of two independent calculations; a rectified average calculation and a Discrete Fourier Transform calculation. These computations will use the data obtained by measurement 2, i.e., the sampled values of voltage V5. Five cycles of the sampled 720 Hz data must be used. Since the measurement data rate was 45,000 words/second, 62 words of data are to be used in the computation. The calculation of a rectified average functional flow is shown in figure 3-11. Initially the measurement data is converted to all positive values. A sum is then taken of these values, and the sum is divided by 100.

Rectified Average Calculation

Convert the first 62 words of data from measurement 2 to positive numbers.

Sum the data

Divide the sum by 100.

Figure 3-11. Functional Flow of the Rectified Average Calculation

The Discrete Fourier Transform (DFT) portion of the program will be used to find the 720 Hz frequency content of the first 62 words of the data of measurement 2. The definition of the DFT is as follows:

$$G(e^{j2\pi f}) = \sum_{i=0}^{N-1} g(n)e^{-j2\pi fn}$$

$$G(f) = \sum_{n=o}^{N-1} g(n)\ (\cos 2\pi fn - j \sin 2\pi fn)$$

$$\left|G(f)\right| = \sqrt{(\text{Real})^2 + (\text{Imaginary})^2}$$

In order to make the routine usuable for any frequency and any signal, the frequency "f" and the number of samples "N" shall be calculation parameters. A funtional flow of the DFT is shown in figure 3.12. The flow is initialized by setting the word count "n" to zero and the cosine and sine sums to zero. Next the phase angle is calculated. The cosine and sine is then taken of this phase angle to form two constants which are then multipled by the data word "g(n)". The cosine and sine sums are formed by adding the result of these multiplication respectively for each n. The above is iterated until all the data has been processed. Once this has taken place, the magnitude of the DFT is found by taking the square root of the sum of the squares of the cosine and sine sum terms.

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PRODUCTION MEASUREMENT OF FUZE COMPONENTS UNDER DYNAMIC STRESS.(U)

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DDC

DFT (f,N)

Initialize

Set the count and the cosine and sine sums to zero

Calculate the phase angle i.e.

$\emptyset = 2\pi f n$

Find cosine and sine of phase

$C = \cos(2\pi f n)$

$S = \sin(2\pi f\ n)$

Find cosine and sine components of the DFT

$A = g(n) * C$

$B = g(n) * S$

Compute the cosine and sine sums

$$scos = \sum_{n-0}^{N-1} A$$

$$ssin = \sum_{n=0}^{N-1} B$$

C

Figure 3.12 DFT Functional Flow

Determine if all the data has been processed (n = N-1). Continue previous calculations until all data is processed.

When all the data has been processed find the magnitude of the component at frequency "f";

Magnitude = $\sqrt{(scos)^2 + (ssin)^2}$

Thresholds and Current Generator Calculations (measurement data 3 and 4)

The thresholds and current generator calculations consists of a linear least mean square fit to the data obtained in measurements 3 and 4. Additionally, a certain amount of data filtering is required to insure that only valid data is used.

Both the data filtering technique and the least mean square fit calculations are common to calculations 3 and 4. The functional flow of the calculation is shown in figure 3.13. First, the table of V6 values is examined. Each entry is examined in succession until the value exceeds a given minimum. (This minimum will be determined when about 100 fuze components become available). For the remaining V6 data, successive values of V6 are averaged and stored as the higher indexed value, i.e.

$$V6(n) = \frac{V6(n) + V6(n-1)}{2}$$

Then every 50th entry of V5 and V6 is to be identified.
(NOTE: the actual entries need not be moved into separate tables). The values so identified shall be used in any standard linear least mean square fit program. (An acceptable procedure is given in "Numerical Methods and Fortran Programming" by McCracken and Dorn.)

The resulting slope of the fit is set equal to current gain and the V5 intercept is the threshold. In the later description of the control functions, values found using measurement 3 will be referred to as threshold 1 and gain 1 and the results using the data of measurement 4 will be referred to as threshold 2 and gain 2.

Threshold and Gain Calculation

Find count in table of V6 values at which the magnitude of V6 exceeds the minimum; i.e. find n for which

$$|V6(n)| > Vmin$$

Average each two succesive values of V6 and store as the higher indexed value;

$$V6(n) = \frac{V6(n) + V6(n-1)}{2}$$

Identify every 50th entry of V5 and every 50th entry of the corrected V6. (Note: Data should not be physically moved)

Calculate the least mean square fit of the data using V6 and V5.

Set the resulting slope equal to the amplifier current gain and V5 intercept equal to threshold and log the results

Figure 3.13 Functional Flow of the Threshold and Gain Calculation

Filter Impulse Response (Measurement data 5)

The mathematical form of the impulse response is

$$h(t) = Ce^{P1t} + De^{P2t}$$

The algorithm to obtain the parameters in the above equation given the step response measurements has not yet been finalized. Until this is completed, the nominal values must be used;

$P_1 = 22.5$

$P_2 = 32.5$

$C = 2$

$D = 2$

SCR Firing Voltage (Measurement data 6)

The algorthm for obtaining the SCR firing voltage to the required accuracy will not be finalized until approximately 100 fuze components are available and have been tested.

Again the use of a nominal value of

V(Fire) = 0.45 volts

shall be used until better data is available.

3.6 Required Gain Calculation

An iterative procedure will be used to calculate the required gain of the amplifier. The technique employed will temporarily assume linearity; rescale the gain based on this assumption; check, using the actual non-linear configuration to determine if the new gain is within required limits; and then iterate until the new gain is within limits. A key element in this process is the determination of the response of the filter to the M wave described in section 2. This determination is discussed first. A straight forward calculation of the gain is greatly complicated by the fact that the input to the filter is a non-linear, full wave rectifier with each section having a different current gain, and each section having a different threshold.

Further, even after the output of the full wave rectifier has been derived, the output of the filter itself must be calculated using a complex convolution integral.

In order to achieve a realistic execution time for this calculation, a table look up scheme is used in place of the calculation relating to threshold effects, full wave rectification, and convolution. The form of the table is shown in figure 3.14. It is a two dimensional array, the vertical dimension being the pole value. More accurately, it is the rescaled pole value, so that the entries will be integer numbers, where the rescaling takes place in calculation 5. The horizontal dimension is percent threshold to signal. The actual value of the entries for both dimensions are as shown in figure 3.14. These are approximate values which can be used for checkout purposes. Precise values will be derived as part of the on going simulation effort.

The convolution integral must be found separately for each pole and threshold combination. Figure 3.15 is a functional flow chart of the required procedure. The quantities of pole value, threshold, and gain to point 5 are used to determine the pole interpolation factor and the percent threshold interpolation factor. The value of the integral is then found using linear interpolation on the two dimensional Convolution Integral table.

The iterative gain calculation loop functional flow chart is shown in figure 3.16. First the integrals, Int (i,j) are found corresponding to each pole and threshold combination, then the effect due to the first threshold and current

Threshold/Signal * 100

Pole Value	0%	5%	10%	100%
20	100.	99.	98	69.
25	101.	100.	99	70.
30	102.	101.	100	71.
2000	288.	287.	286	257.

Figure 3.14 Convolution Integral Table

Convolution Integral

Determine integer value of pole

Label the corresponding row "k"

Find pole interpolation factor

$$\lambda = \frac{\text{Pole Value - Pole Integer Value}}{5}$$

Find % threshold

$$\%\ \text{Threshold} = \frac{\text{Threshold * 100}}{\text{Gain to Point 5}}$$

Find integer value of % threshold

Label the corresponding column "ℓ"

Find % threshold interpolation factor;

$$\beta = \frac{\text{Threshold - \% Threshold Integer Value}}{5}$$

Linearly interpolate between pole rows and between threshold percent columns to find the convolution integral as required.

$$\begin{aligned} INT(I,J) &= I(k,\ell) + \beta\left[I(k,\ell+1) - I(k,\ell)\right] + \lambda\left[I(k+1,\ell) - I(k,\ell)\right] \\ &\quad + \lambda\beta\left[I(k,\ell) - I(k+1,\ell) - I(k,\ell+1) + I(k,\ell)\right] \end{aligned}$$

Figure 3.15 Functional Flow Chart of Convolution Integral Determination

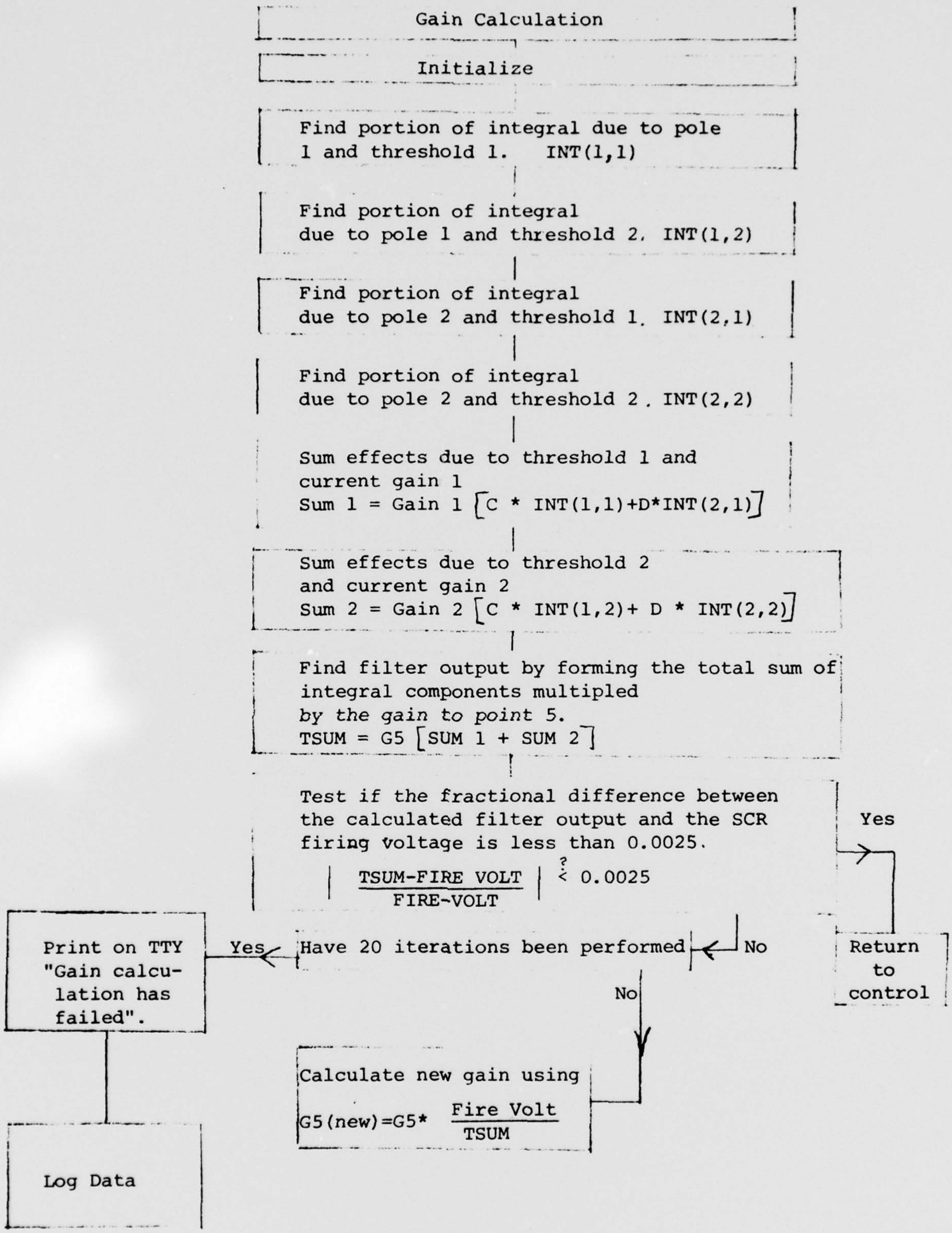

Figure 3.16 Gain Calculation

gain (as found in parameter calculation 3) is determined. "C" and "D" are constants determined from parameter calculation 5. Next the effect due to the second threshold and gain is calculated. Then the two effects are summed and multiplied by the gain to point 5 (parameter calculation 2). This sum is the voltage at the SCR due to the M wave at the specified height if the gain to point 5 is indeed equal to "G5". A test is made to determine if the fractional difference between the voltage at the SCR and the SCR firing voltage is less than 0.0025. If it is, the calcualtion has been successfully concluded. If the test criteria is not met, a check is made to determine if 20 iterations have taken place. If so, it is concluded that the program has failed. This is indicated on the TTY and the result is data logged. If not, a new required gain to point 5 must be calculated using the linear assumption technique.

3.7 Trim Calculations

When the gain calculation is successfully completed, the change in the divider resistor is calculated (see figure 3.17). The formula for the fractional change in resistance is shown in the functional flow chart. The double primes refer to the required value and the single prime to the actual measured value. The required length of cut is found by a table look up and linear interpolation. This table will be supplied when the trimmable resistor design is finalized. 5% is subtracted from the total trim length and the laser is ordered to cut to this shorter length at a rate of 2 inches/second. The final cut to complete the last 5% of length is taken at a slow rate of 0.1 inches/second while the voltage at point 5 is sampled and the gain continously calculated using the last five cycles of carrier. When the voltage reaches the required value, the laser is stopped, and the trim operation is complete.

TRIM

ORDER LASER CW OUTPUT

CALCULATE

$$\frac{R''}{R'} = \frac{K''}{(1-K'')} \frac{(1-K')}{K'}$$

Where: K"=DC Attenuation (measurement 1)

$$K''=K' \frac{G5\,(\text{Required})}{G5\,(\text{measured})}$$

FIND ENTRIES IN TABLE GIVING LENGTH of CUT WHICH STRADLE

$$\frac{R''_L}{R_L'}$$

INTERPOLATE TO FIND LENGTH

SUBTRACT 5%

CUT TO LENGTH

READ V5

MAINTAIN RUNNING AVERAGE OF V5 FOR LAST FIVE CYCLES OF THE SIGNAL

SHADOW CUT UNTIL GAIN COMES TO WITH 0.1% OF DESIRED GAIN

CALCULATE TRIM TIME

DATA LOG
RECORD ALL INTERMEDIATE DATA, TEST RESULTS, FINAL RESULTS, AND TIME PER TRIM

Fig. 3.17
Trim Calculation and Trim Command Functional Flow Chart

3.8 Data Log

Results of the computations performed are logged as indicated on disk. The data shall contain, as a minimum, whether trim has been accomplished and the time to trim the amplifier. Further data logging requirements, beyond those already indicated if any, will have to be as per customer request. Provision shall be made to log additional data items.

3.9 Word Size and Accuracy Requirements

All input measurements and output stimulus data words are to be 12 bit integer numbers. Preliminaty results from simulation efforts indicate that there will be negligible computational error due to word size limitations if the data is internally converted to a fortran real number and all calculations are performed using floating point arithmetic.

4. Oscillator Test and Trim Program Functional Requirements

The oscillator test and trim program is a single loop measurement and trim procedure. The functional flow of the process is shown in figure 3.18. The functions indicated are either identical to functions performed in the amplifier test or similar requiring some minor modifications. The functional flow is therefore self-explanatory.

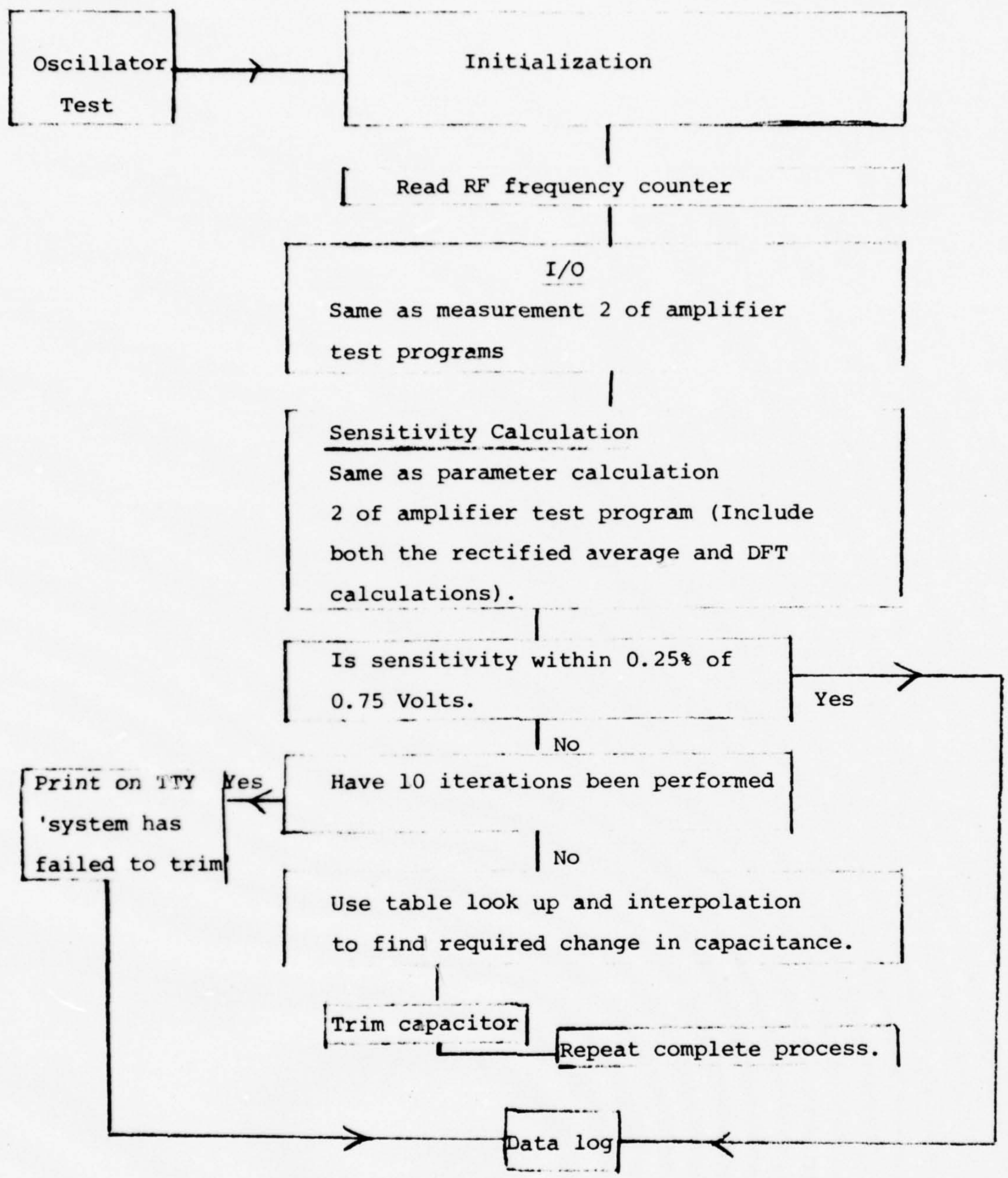

Figure 3.18. Oscillator Test and Trim Functional Flow.

5. <u>BITE Programs</u>

The BITE programs shall be identical to the amplifier and oscillator test and trim programs with only minor additions. The additions are the following:

1. The initialization process shall include a command to energize relay 11 or 12, the relays which bring in a standard test amplifier or test oscillator program respectively, instead of the unit under test.

2. Data logging as indicated in the functional flows shall be replaced with a comparison of all input data and calculations against stored, correct values. Differences greater than 10% shall be printed on the TTY. If such differences do not occur, "SYSTEM CHECK OF $\frac{\text{AMPLIFIER}}{\text{OSCILLATOR}}$ OK" shall be printed on the TTY.

3. The laser shall <u>not</u> be energized during the trim routine. Instead, the final position determined from a trim calculation shall be compared to the command position. If any difference exists "LASER POSITION FAILURE" shall be printed on the TTY; otherwise print "LASER SYSTEM POSITION CHECK OK".

4. Read laser status word. If indications are that no failures are present print on TTY "LASER STATUS OK"; if failure is indicated print on TTY "LASER SYSTEM FAILURE" and then print on TTY the laser status word.

APPENDIX B

INTEGRATION SPECIFICATION

FOR TEST STATION FOR

CONTRACT DAAB07-76-C-0032

ISSUE 1

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S. Feldman

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1.0 INTRODUCTION

This specification is to be used to test the integration of the following major elements of the ECOM Test Station:

- Computer Control Subsystem
- Stimulus Subsystem
- Measurement Subsystem
- Interface Subsystem
- Laser Trimmer Subsystem
- Modulator

An overall description of the above elements of the system is given in the next section. A detailed description of the individual hardware and software components is available in manuals delivered with the equipment.

2.0 SYSTEM DESCRIPTION

The test station system design is an extension of third-generation design principles. It contains the following basic elements:

- Computer control
- Computer-generated stimuli
- Computer-controlled sampling system
- Computer-controlled interface
- Computer calculation of parameters from sampled data
- Computer controlled laser trimmer

An important addition has been made to the third generation system in the form of the computer-controlled, real-time, trim capability. A laser trimmer was chosen to perform this function. This unit, under computer control, is capable of either trimming thick-film resistors and capacitors or cutting printed wiring leads to disconnect discrete components. Thus, in addition to being automatically tested, units can be tuned or trimmed to bring them within specified limits.

Hewlett-Packard Equipment

The system concept is shown in Figure 2-1. Specific hardware has been chosen to implement this system. All the major hardware, except the laser, are catalog items from Hewlett-Packard. Figure 2-2 is

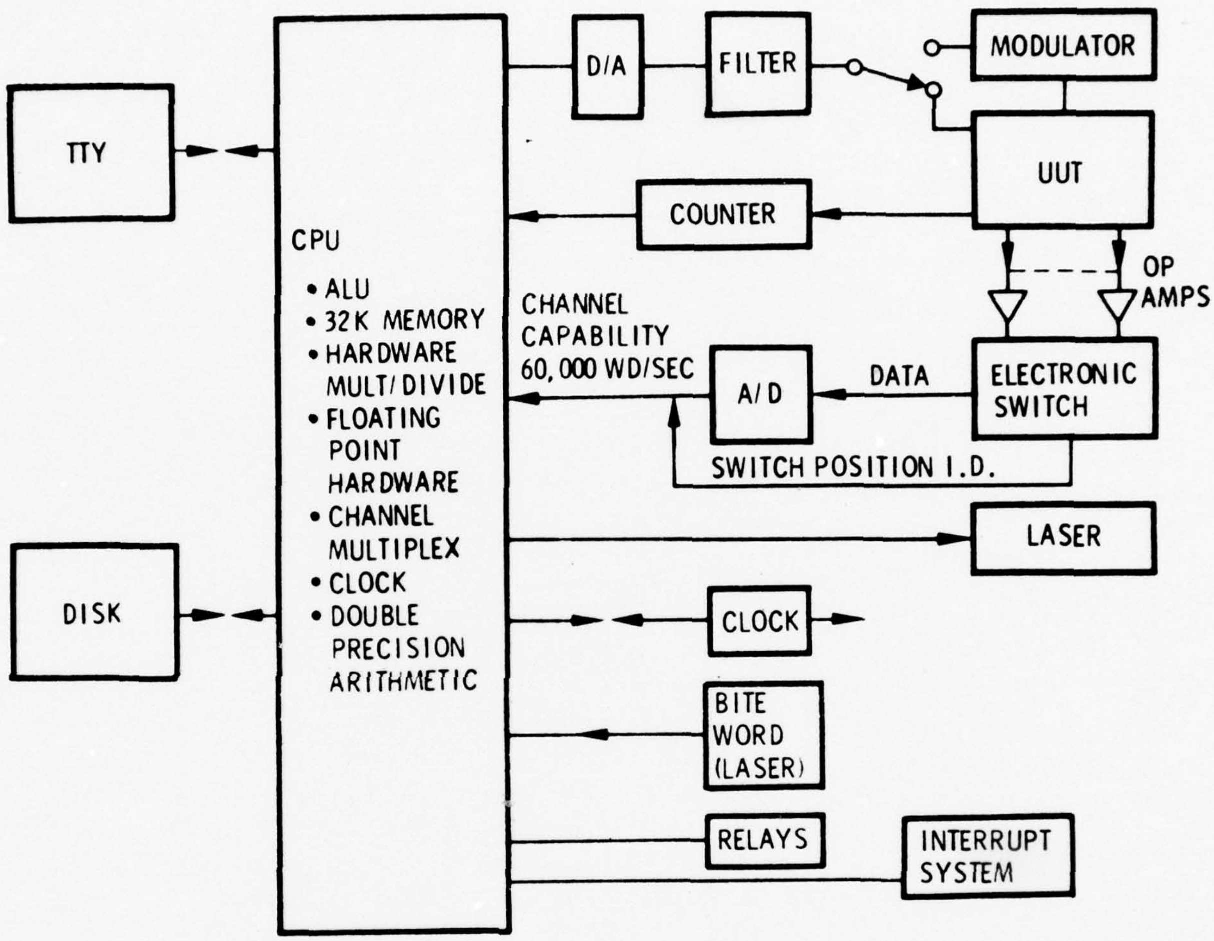


Figure 2-1. Test and Correction System

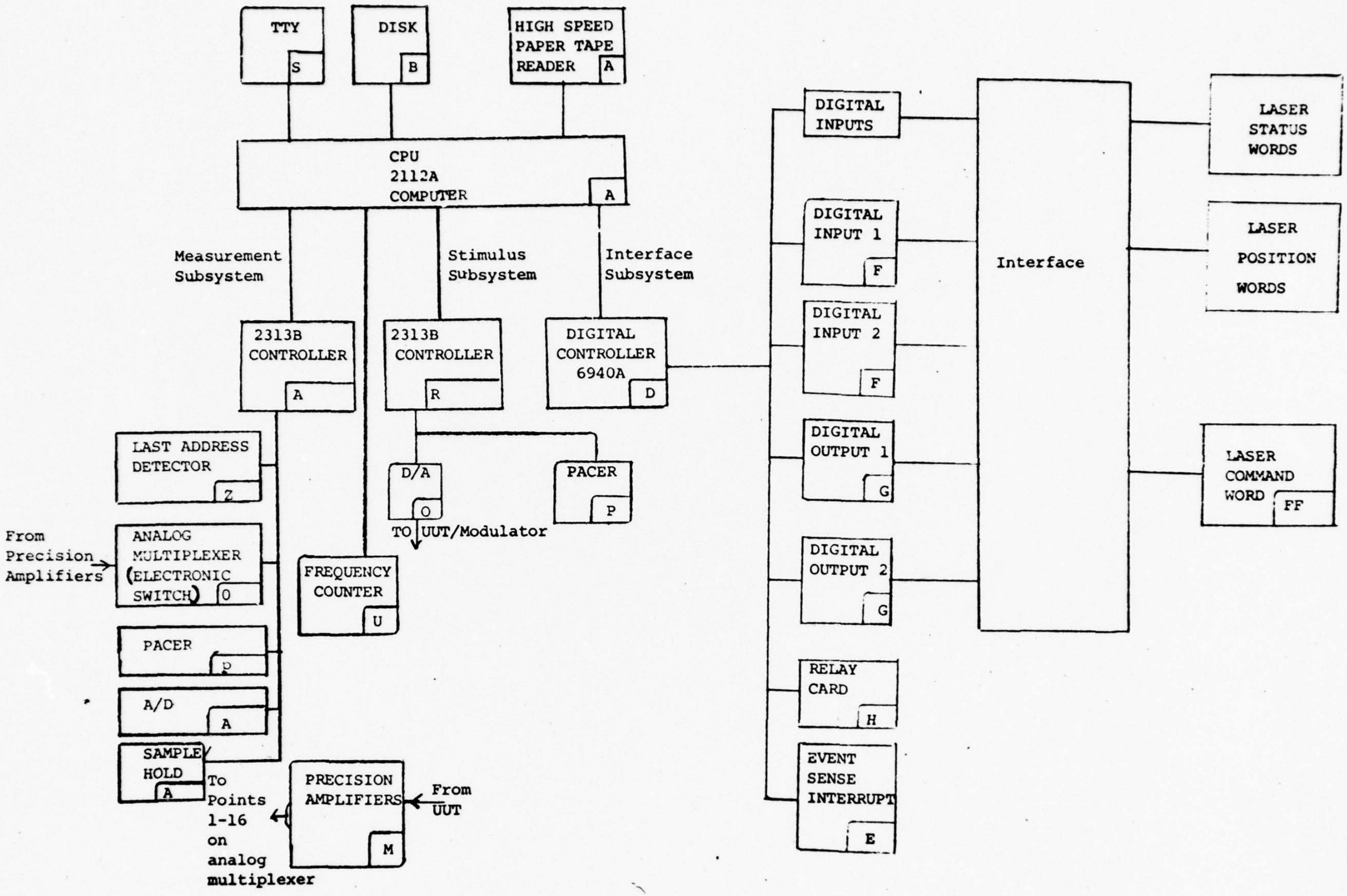


Figure 2-2

Computer and Computer Peripherals

a block diagram in which the major components are shown. The letters in the lower corners of each unit, in this figure, relate to equipments listed in Table 2-1. This table is a list of the catalog items with their catalog numbers. Referring to Figure 2-2, it is seen that the central computer is a Hewlett-Packard 2112A unit. This computer is a 16-bit minicomputer. It is being purchased with 32K of memory, which minimizes the need for program overlap during real-time operation. The computer will come with firmware for multiply/divide, floating-point arithmetic, double-precision arithmetic, 14 multiplexed I/O channels, an internal clock, and two DMA channels. A control panel is provided on the computer. This panel, in conjunction with the TTY, will provide the operator interface during program development and actual testing.

The operating system consists of a 4.9M byte disk, a paper tape loader, and the associated real-time executive programs. The disk will also provide storage for all the real-time programs. Data logging will be on the disk.

The stimulus subsystem starts within the computer itself. Either by program or external entry, a table is made to describe the shape of the desired stimulus waveform. Upon program command, this table is outputted through a DMA channel to the Hewlett-Packard 2313B Controller (labelled R in Figure 2-2). In turn, the controller routes the words to a 12-bit D/A converter. The stimulus system is capable of outputting digital words at a rate limited by the DMA channel (i.e., 600,000 words/minute). The D/A converter is capable of a settling time of 20 microseconds. The output rate is controlled by the pacer (P in Figure 2-2) which is programmed by the computer.

The measurement system starts with the precision amplifiers (Unit M) shown in Figure 2-2. The amplifier outputs are routed to the analog multiplexer labelled 0 in this figure. In effect, the multiplexer is part of the switching system, since it is programmed by the computer to sample from 1 to 16 consecutive positions and then to repeat these samples continuously. The multiplexer can also be used in a mode in which a sequence of arbitrary positions, stored in the computer, will be executed.

Table 2-1

Major Purchased Items

Hewlett-Packard Catalog Items for Tester

Item	Quantity	Description
A.	1	HP 9603A High-speed Measurement and Control System.
B.	1	Option #A03: RTE-II with 4.9M Byte Disc, Cabinet, Fortran IV, System Libraries.
C.	1	Option #Y13: Batch Spool Monitor.
D.	1	Option #T17: 6940A (91063A) Digital I/O Subsystem.
E.	1	Option #J17: Event Sense Interrupt.
F.	2	Option #J16: Isolated Digital Input, 12 bits.
G.	2	Option #K04: TTL Output, 12 bits.
H.	1	Option #K05: Relay Output Card.
I.	1	Option #P24: Replace 2108A with 2112A.
J.	1	Option #R00: Teleprinter and Local I/O, 10 cps.
K.	1	Option #005: Additional I/O for 2313B.
L.	1	Option #021: 10 ft. Differential Cable.
M.	3	Option #025: 2471A Data Amplifier.
N.	1	Option #026: Case for 2471A Cards

Table 2-1

(cont'd)

Item	Quantity	Description
O.	1	Option #008: 16-Channel High Level Multiplexer.
P.	2	Option #011: Programmable Pacer (12755A).
Q.	1	Option #013: D/A Dual 12-bit Converter.
R.	1	Option #558: Second 2312B-001 Integrated into 9603A.
S.	1	Option #P12: 16K Word Memory Expansion.
T.	1	HP 59310B HP-IB Interface Card.
U.	1	HP 5341A Frequency Counter to 4.5 GHZ.
V.	1	Option #002: Rear Panel Connectors
W.	1	Option #003: 1.5 GHZ Frequency Range.
X	1	Option #011: I/O ASCII Interface
Y	1	Option #908: Rack Flange Kit; HP Part No. 05326-60046.
Z	1	Last Address Detector
		Quantrad Corporation
	1	Laser Trimmer Model 1021

The output of the analog multiplexer is fed to a sample-hold and then to a A/D converter; from there, the DMA channel reads the words into the computer. A pacer (O) accurately times the transfer rate. Again, the pacer rate is set by the computer.

For the specified accuracy of ± 0.09-percent full-scale, $\pm 1/2$ LSB the maximum rate into the computer is 45,000 words per second.

The Hewlett-Packard Digital Controller shown as Unit D in Figure 2-2 handles low-speed digital input/output. The output commands to the laser and the laser BITE word will run through this multiplexer. Additionally, the event sense interrupt is controlled by this unit. The event sense unit can be set to interrupt the computer, based on matching a bit reference word. Since there are 12 bits in the reference word, there are 2^{12} (or 4,096 independent events) that can interrupt the computer.

A relay card (Unit H) consisting of 12 single-pole, single-throw relays is also computer-controlled through the digital multiplexer. Additional relay cards can be inexpensively obtained. These relays, together with the analog multiplexer, form the computer-controlled interface. The frequency counter (Unit U) can read RF frequency up to 1.5GHz.

Except for the frequency counter, this system is essentially a low-frequency system. It is limited by the DMA rate to 600,000 words per second. However, the frequency range can be extended to include RF and microwave test and trim by adding external buffering, RF synthesizers, and an RF spectrum analyzer.

Laser Trimmer

General Description

The Model 1021 Laser Trimmer consists of the following major assemblies:

a. YAG Laser

b. Optical Subsystem

c. Beam Positioner

The laser is a high powered continuously pumped Nd: YAG Oscillator. It uses an acoustic-optic Q-switch to achieve short, high-power pulses of infra-red light which are useful in material removal applications.

The optical subsystem consists of optics which direct the laser beam (the beam positioner), provides for binocular viewing of the work area, and provides for viewing on a TV monitor. The beam positioner uses moving prisms to optically sweep the laser beam over the work area. The stage is motor-driven by commands from a customer-provided computer.

A functional block diagram of the trimmer is given in Figure 2-3.

Laser Description

General Description

The laser consists of two modules; the laser power supply and the laser head.

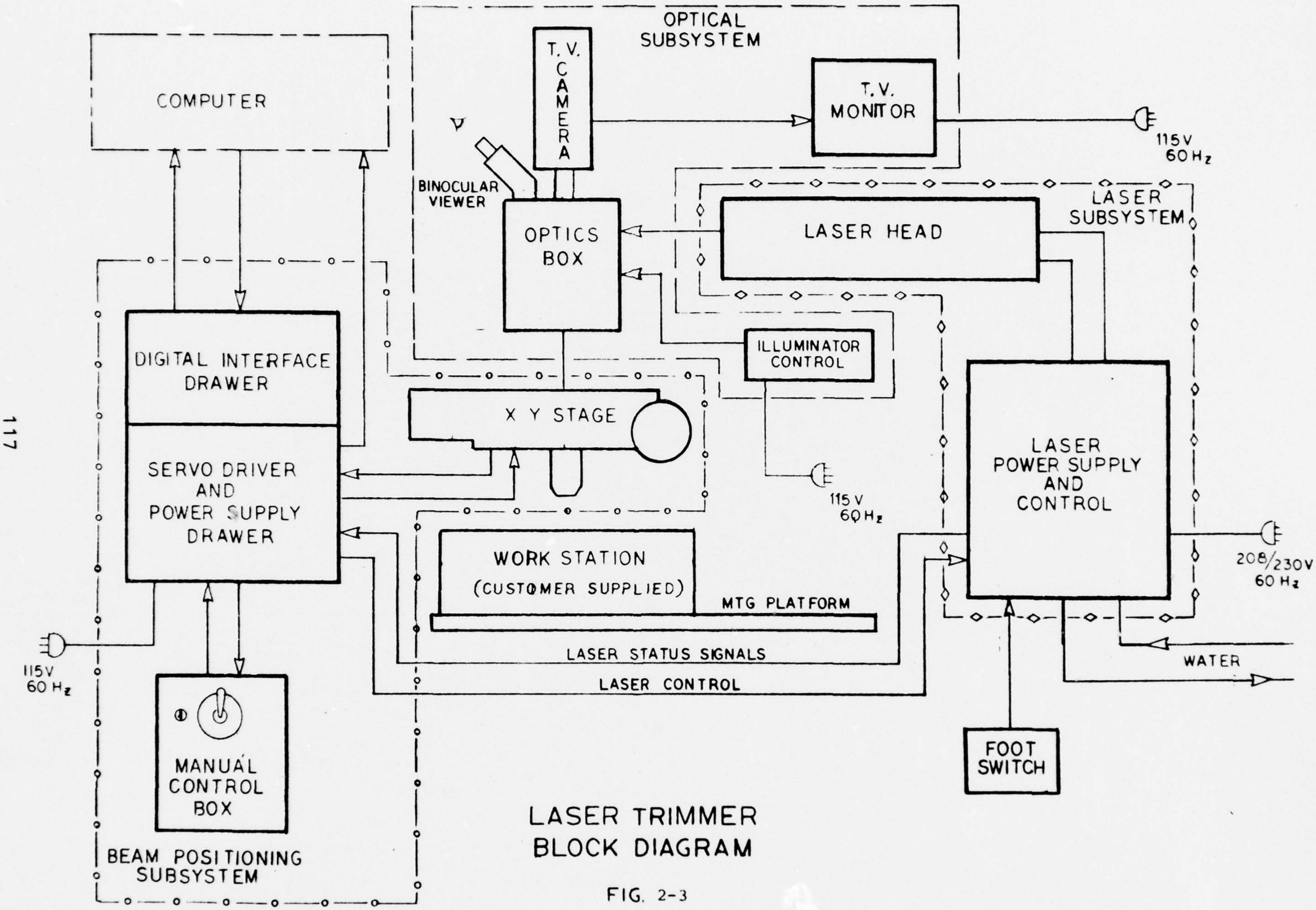
The power supply cabinet contains the pump lamp power supply, the RF driver for the acousto-optic Q-switch, the water-to-water heat exchanger, and the laser controls.

The head assembly consists of the laser pump cavity, the optical resonators, and Q-switch. A 2.5 KW krypton-arc lamp is used to optically pump the YAG laser rod. A safety shutter insures positive and quick shut off of laser output.

Figure 2-4 indicates the functional block diagram of the laser subsystem.

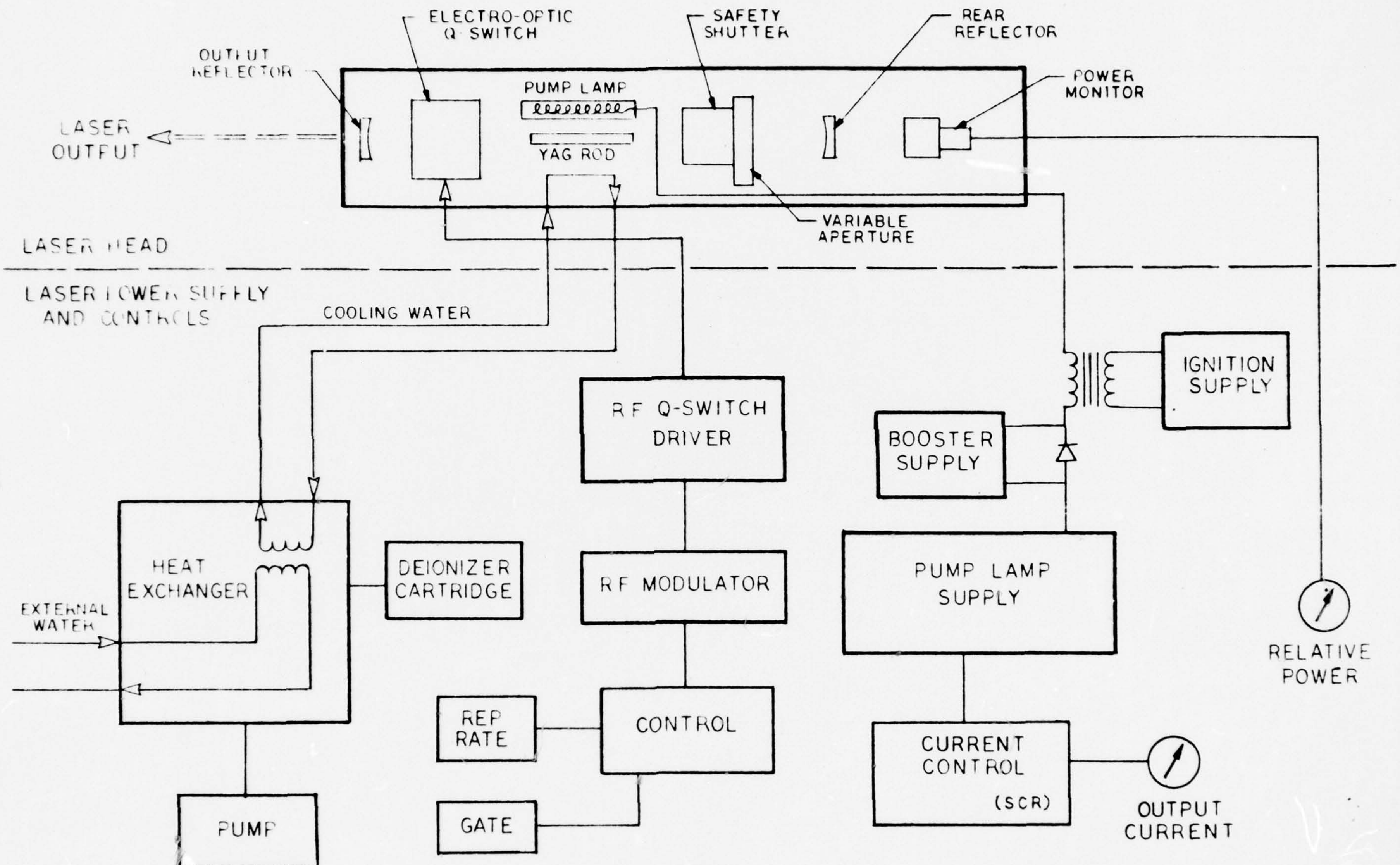
Specifications

CW Power Output	30 watts, multimode 4 watts, TEMoo
Peak Power Output	3 KW TEMoo from 1KHz to 6.5KHz 2 KW TEMoo from 6.5KHz to 10KHz
Average Power Output	2.5 watts at 5KHz, TEMoo 3.5 watts at 15KHz, TEMoo
Mode Selection	Integral iris diaphram
Cooling	Integral water-to-water heat exchanger
Safety Interlocks	High/low water pressure High/low temperature
Monitor	Integral elapsed time meter for pump lamp



LASER TRIMMER
BLOCK DIAGRAM

FIG. 2-3



LASER
BLOCK DIAGRAM

FIG 2-4

Prime Power	208/220V, single phase, 60Hz, 25 amps
Water Requirements	3 gallons per minute max, 90 gallons per hour average flow, 75°F max temperature

Optical Subsystem Description

General Description

The optical subsystem consists of the optics enclosure which contains the beam expanding telescope, the trinocular head, the illuminator, the TV camera, and TV monitor. Figure 2-5 depicts the optical train. The circuit to be trimmed may be viewed through the binocular eye-piece or on the TV monitor. Laser spot size selection is provided by adjusting the iris and spot size knob on the control panel of the optics box.

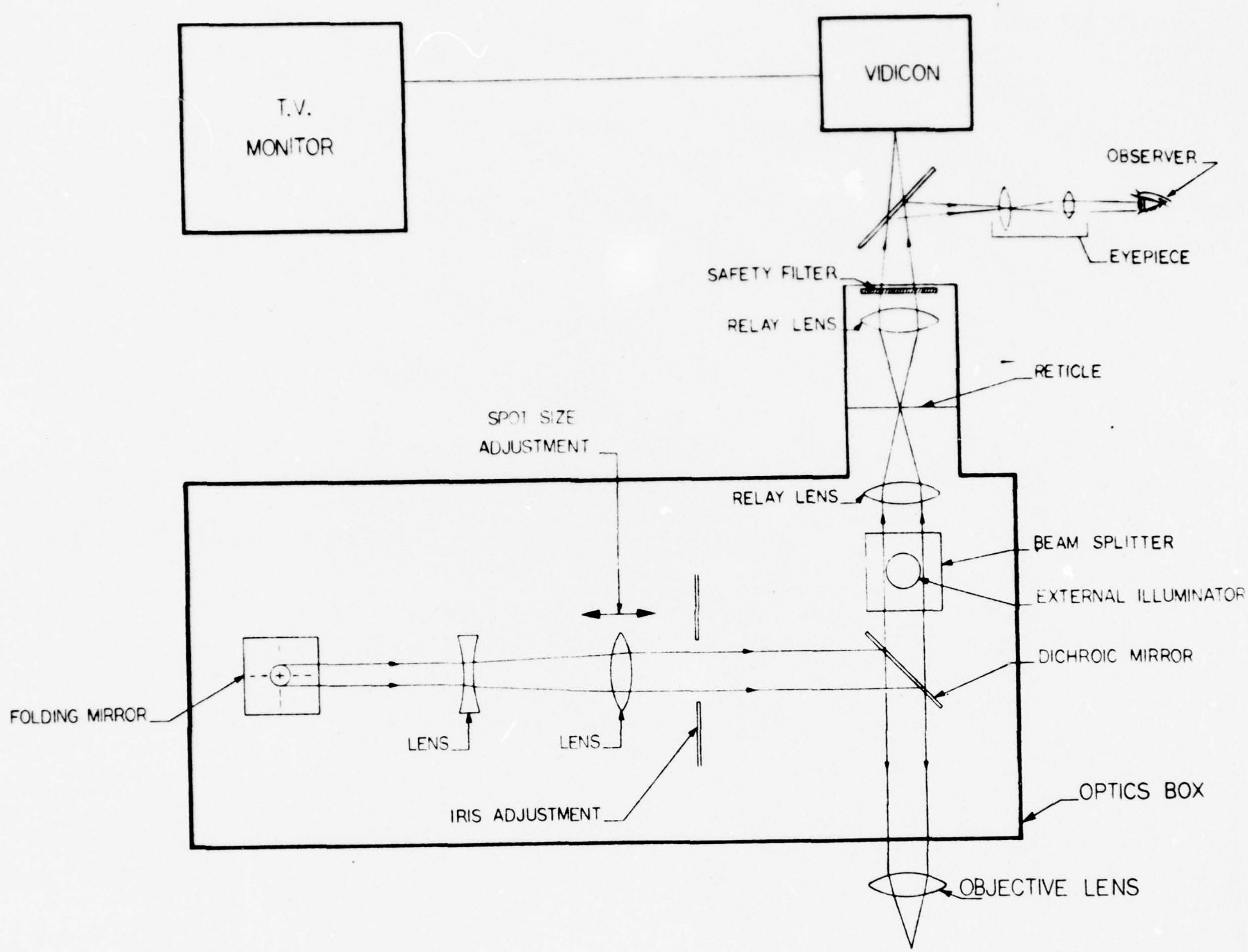
Specifications

Spot size adjustment	From 0.001 inch to 0.005 inch with 2-inch objective lens
Controls:	
Illuminator intensity	Controls illumination of work
Iris	Controls diameter of exit beam
Spot Size	Control divergence of exit beam
TV Camera	2/3-inch vidicon
TV Monitor	9-inch CRT

Beam Positioner Description

General Description

A modified beam positioner is used in this system, designated the Model 708S. It is a digitally-encoded, servo driven beam positioner, capable of receiving and storing position commands from the computer output. It then generates the necessary velocity commands to a servo positioning system to cause the beam to assume the programmed position. Three modes of operation are capable of being selected; two automatic and one manual. In the automatic slew mode, commanded by computer control, the X-Y positioner slews at a rate of 5 inches/second to the position being addressed, moving simultaneously in the X and Y direction with an acceleration and deceleration program resulting in minimum



OPTICAL SUBSYSTEM SCHEMATIC

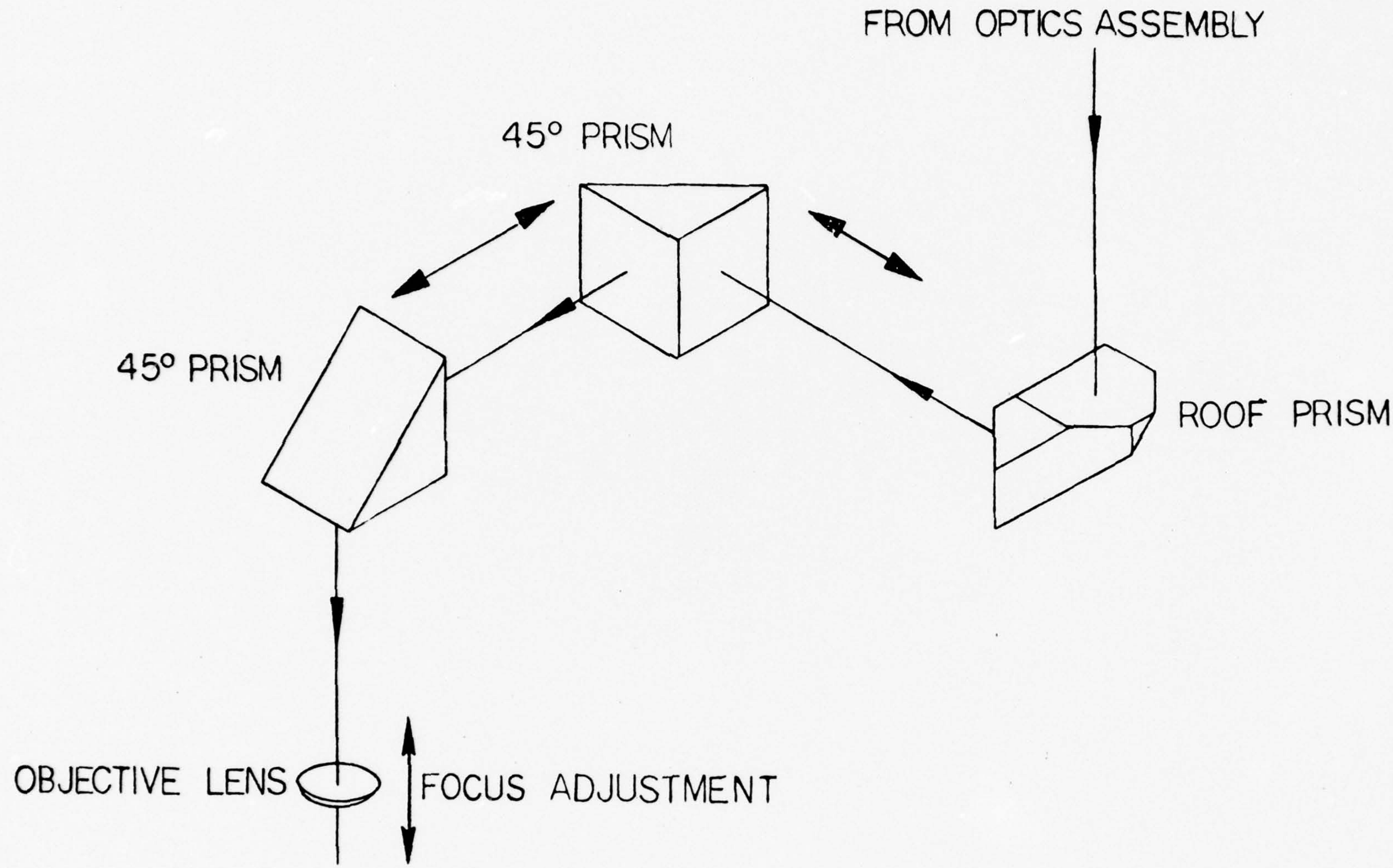
FIG. 2-5

positioning time consistent with a positioning accuracy of ±1/2 of the least significant bit. In the automatic trim mode, the beam positioner moves at an adjustable steady state rate of up to 400 mils/second, the motion being confined to either axis. Acceleration and deceleration rates are consistent with minimum trim times making use of synchronous laser triggering to provide a uniform density of laser energy/unit length of trim cut. In the manual mode, the computer interface no longer controls the beam position or laser triggering. Control is transferred by means of a front panel key switch to a two-axis joystick providing proportional velocity control in the desired directions. Laser triggering is either synchronous or asynchronous as selected from the laser front panel. The computer interface also supplies status monitoring signals to the computer including the two position encoder outputs and systems data outputs from the laser and the control system.

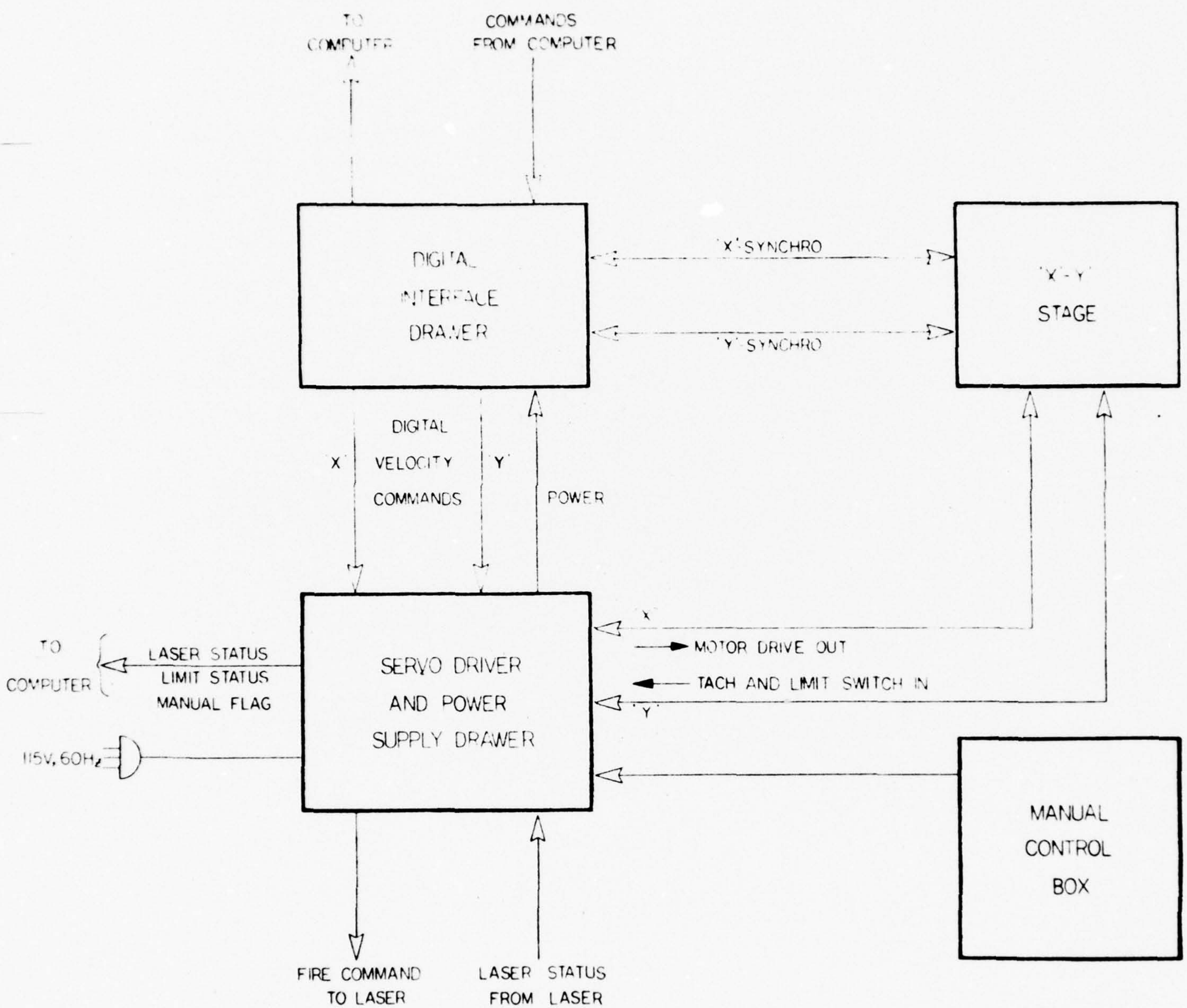
The optical path followed by the laser beam is illustrated in Figure 2-6. Figure 2-7 is a functional block diagram of the beam positioner electronics. The principal functions of the servo drawer and interface drawer are shown in block diagrams, Figures 2-8 and 2-9, respectively.

General Specifications

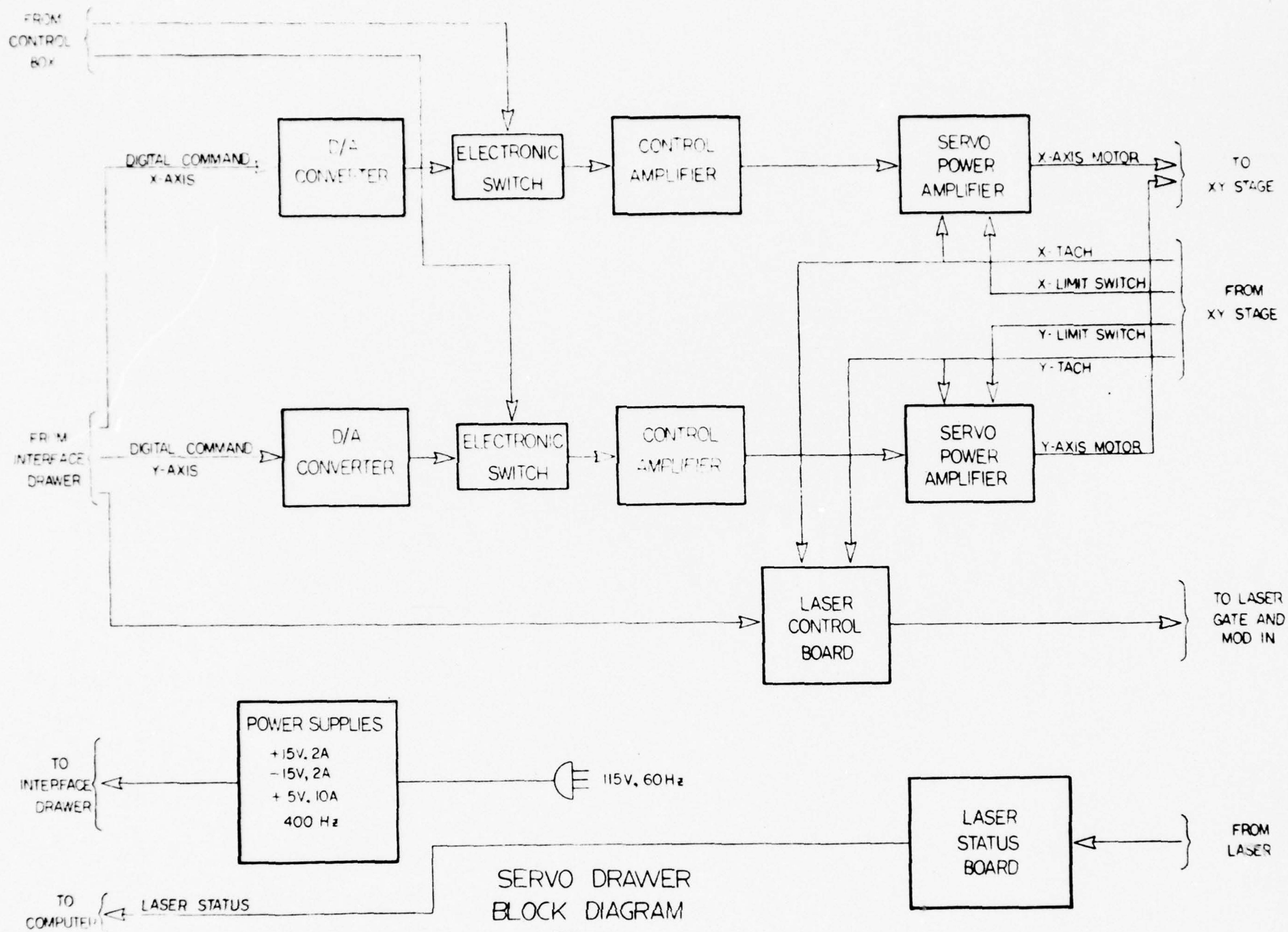
Positioning Range	2.0 inches x 2.0 inches
Positioning Accuracy	±0.25 mils
Positioning Rate - Slew	5"/second in both axis for positioning moves greater than or equal to 125 mils. For moves less than 125 mils, the rate decreases linearly with step length.
Trim Rate	0-400 mils/sec. adjustable for trims greater than or equal to 125 mils. For trim less than 125 mils the rate is proportional to trim length.
Stopping Distance During the Trim	0.5 mils following receipt of command
Laser Overlap	Under panel switch selectable at 25, 50, and 75%



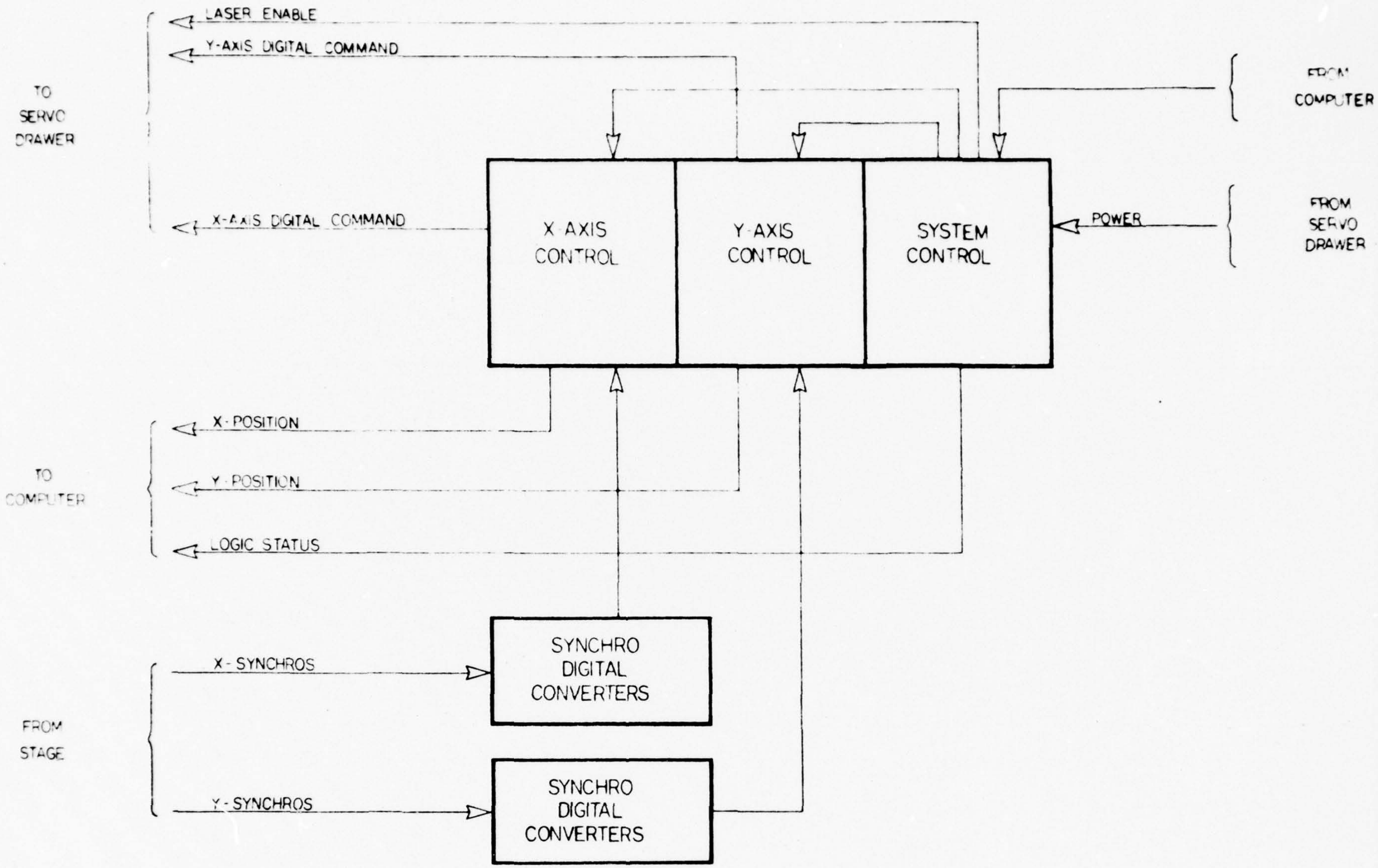
BEAM POSITIONER OPTICAL SCHEMATIC
FIG. 2-6



BEAM POSITIONER
ELECTRICAL BLOCK DIAGRAM
FIG. 2-7



SERVO DRAWER
BLOCK DIAGRAM
FIG. 2-8



INTERFACE DRAWER
BLOCK DIAGRAM

FIG.2-9

Manual Operations	X-Y joystick controllable continuously from 0 to 5 inches/sec. switch selectable single or two axis.
Input/Output Logic Convention	Control signals from computer, 25 mA current delivered into a 4N28 photo-isolator located in the 708 interface equals logic "1".
Outputs to the Computer	A logic "1" output consists of sinking 25 mA from a 15V source located in the computer.

Computer Command Protocol

The command words are designated by a 2-bit code appearing on Bits 15 and 14 and a positive going strobe appearing on Bit 13.

No data equals	bit 15→1; bit 14→1
An X command equals	bit 15→1; bit 14→0
A Y command equals	bit 15→0; bit 14→1
A control command equals	bit 15→0; bit 14→0
25 mA equals	Logic "1" data to remain until the x ready status bit goes to zero.
Word 1	12-bit binary x positive, bits 1-12
Word 2	12-bit binary Y position same convention as Word 1.
Word 3	Bit 1 - Laser enable equals logic "1" Bit 2 - Laser inhibit equals logic "1" Bit 3 - Execute equals logic "1" Bit 4 - Trim equals logic "1" Bit 5 - Home equals logic "1" Bit 6 - Trim complete equals logic "1"

Computer Command Description

Binary X-Y position is measured from an origin located at the extreme left hand forward position of the beam. X position increases at the rate of 125/128 x 0.5 mils per least significant bit in the right hand direction facing the trimmer and Y position increases at the same

rate to the rear of the equipment. A laser enable command permits the laser to come on provided: 1) that the system is in the "trim" and not in the "slew" mode, and 2) that motion is taking place and that laser inhibit is zero. Laser inhibit absolutely inhibits the laser independent of all other commands. Execute must be in the one condition in order that the system move to a new address. Execute must go to zero and back to 1 before a new address can cause motion. Trim sets the beam positioner rate to the trim rate and permits the laser to go on provided it is not otherwise inhibited. Trim equals zero puts the system in the slew mode. Home in conjunction with an execute command, causes the beam to return to the X=0, Y=0 position. Trim complete stops the motion immediately upon its receipt if the system is in the trim mode. In the slew mode, it has no effect.

Status Signal Protocol

Bit 1	acknowledge
Bit 2	laser enabled
Bit 3	X ready
Bit 4	Y ready
Bit 5	Manual mode
Bit 6	Not (X minus) limit switch
Bit 7	Not (X plus) limit switch
Bit 8	Not (Y minus) limit switch
Bit 9	Not (Y plus) limit switch
Bit 10	Power on
Bit 11	Water flow OK
Bit 12	Water temperature OK
Bit 13	Water resistivity OK
Bit 14	All interlocks closed
Bit 15	Q-switch RF drive OK
Bit 16	Q-switch temperature OK
Bit 17	Laser power OK
Bit 18	Pump beam current OK
Word 2	12-bit X position, 12 straight binary bits with a data ready line
Word 3	12-bit Y position with data ready line

Status Signal Description

Acknowledge indicates that the control command has been received and may be removed from the input lines.

Laser enabled acknowledges a laser enable command.

X ready indicates that the previous X motion has been completed.

Y ready indicates that the previous Y motion has been completed.

Manual mode indicates that a key switch operated manual override is controlling the system.

The four (limit switch commands) Not (-)X, Not (+)X, Not (-)Y, Not (+)Y, indicate that the system is not inadvertently programmed against a stop and, hence, is incapable of moving. These signals will not normally be used unless the system is manually driven against a stop.

Beam positioner power is an indication that all power supplies required for running the servos are up to voltage.

Water flow OK is a monitor on the flow interlock in the laser.

Water temperature OK is a monitor on the water temperature interlock in the laser.

Water resistivity OK is a monitor of the water conductivity indicating incipient firing difficulties.

All interlocks closed - safety interlocks are closed and the safety shutter is not in place.

Q-switch RF drive OK is derived from the Q-switch driver voltage circuitry.

Q-switch RF drive OK is derived from the Q-switch driver voltage circuitry.

Q-switch temperature OK is a monitor on the Q-switch temperature interlock.

Laser power OK indicates the power exceeding a pre-set threshold as monitored from the relative power meter.

Pump lamp current OK indicates that the pump lamp current is between pre-set limits.

the 12-bit X position and Y position bits will be considered valid only when the X ready and Y ready signals are "1" respectively.

Data ready strobe will be a 100 microsecond minimum duration, "1" state.

3.0 SYSTEM INTEGRATION TESTS

3.1 Computer Control Subsystem Integration Tests

The computer and associated operating system software and hardware checkout is to the detail required for the ECOM Test Station. The full capabilities of the computer and operating system will not be tested.

Test Sequence

1. Turn off power to the computer.

2. Restore computer power and turn on power to the entire system.

3. Load the RTE-II System software
   - Load bootstrap loader
   - Load RTE software

4. Enter date and time of day.

5. Enter the program "SUM" whose functional flow chart is given in Figure 3.1-1. In entering the program, create one syntax error and one run time error so that the compiler and run time diagnostic routines will be exercised.

6. In entering the program, the RTE software, file manager, and editor will be exercised. As a minimum, the following commands should be used:

RTE COMMANDS

*STATUS

*RUN

*OFF

*RTRACKS

FILE MANAGER COMMANDS

:LIST

:DL (Directory List)

:CL (Cartridge Directory List)

:RUN

:PURGE

:RNAME

:RTRACKS

:DUMP

:??

:EXIT

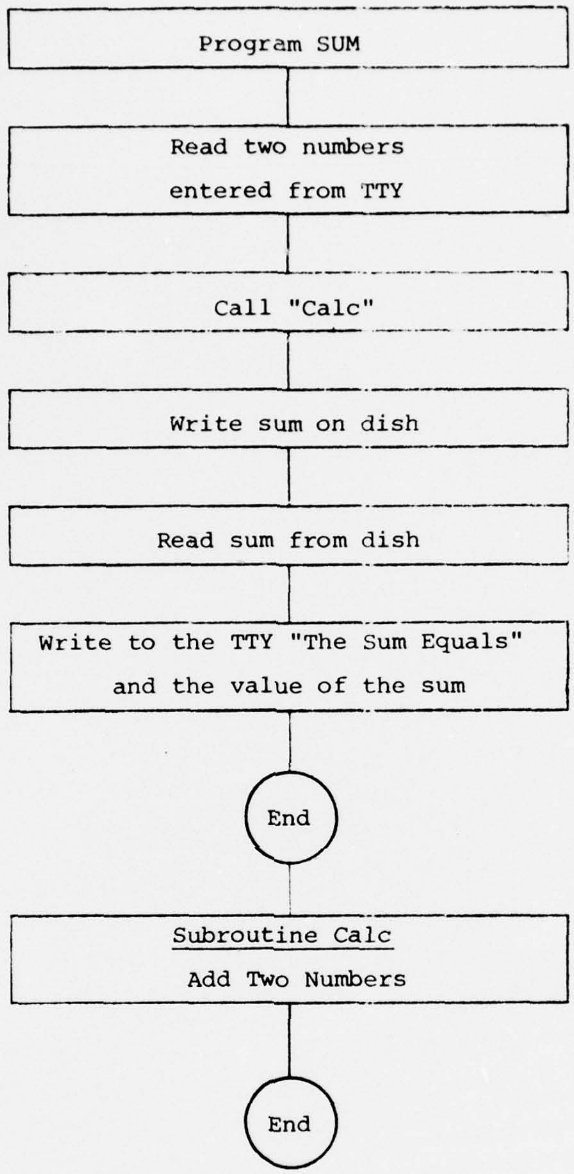


FIGURE 3.1-1

PROGRAM SUM

EDITOR COMMANDS

/REPLACE

/LIST

/NUMBER (designate pending line)

/ER

/EC

/ABORT

7. Compile Fortran Program.
8. Correct errors and compile again.
9. Run.
10. Correct errors, compile, and run again.
11. Check that the correct heading and answer has been printed.

3.2 Stimulus Subsystem Integration Tests

The stimulus subsystem shall be checked as follows. Connect a voltmeter (Zin $\geq$1,000 ohms; range zero to ten or greater) to the output of the D/A. The polarity shall be for measuring positive voltage. Run the program "LINEAR EXCITATION" whose functional flow chart is given in Figure 3.2-1. Type in "GO" to the TTY. Observe that the voltmeter reading rises linearly and smoothly from zero to plus ten volts in two minutes. When the teletype prints out "Reverse Polarity", reverse the voltmeter leads. Type in "GO" at the TTY. Observe that the voltmeter changes smoothly from zero to minus ten volts in two minutes.

3.3 Measurement Subsystem Integration Tests

The measurement subsystem shall be checked as follows. Connect the circuit of Figure 3.3-1 to the analog multiplexer. Run the program "MEASUREMENT" whose functional flow chart is shown in Figure 3.3-2.

After the program run has been initiated, enter "GO" at the teletype. It should then take 48 seconds to where output first appears at the TTY. Observe the output of the teletype and check that elapsed time has been recorded as 48 seconds and that the voltages printed out range from zero to 2,000 in 15 approximately equal steps.

Reverse the polarity of the source voltage and repeat the program. The voltages now printed out should be negative.

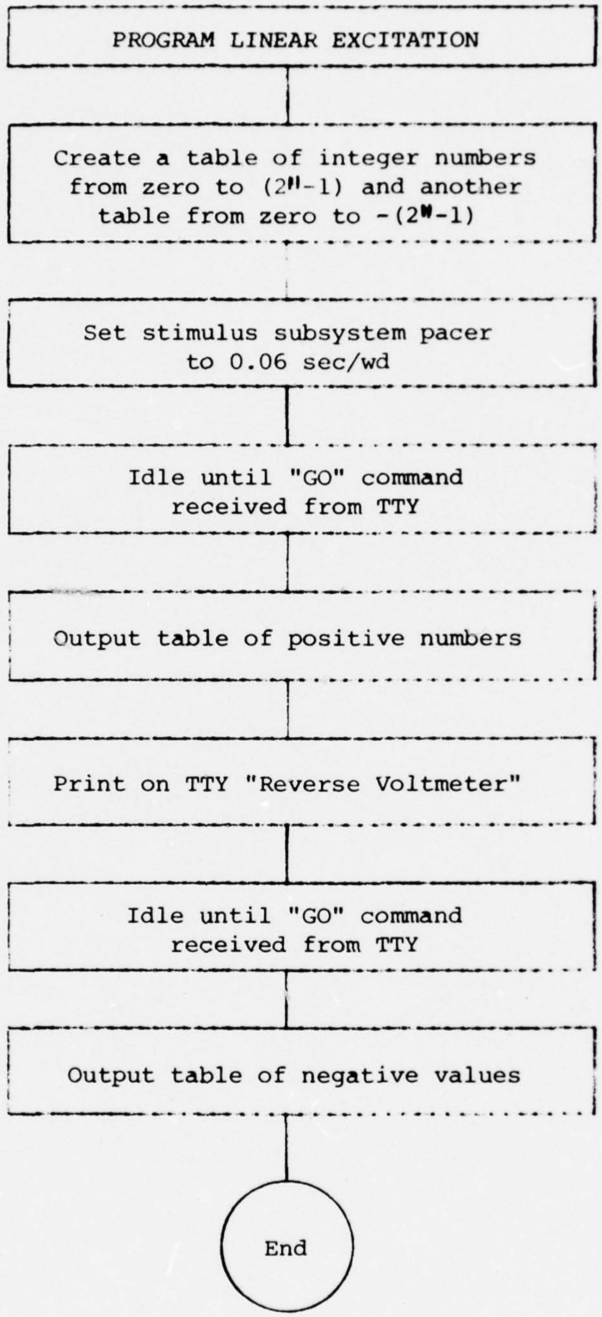


FIGURE 3.2-1

PROGRAM LINEAR EXCITATION

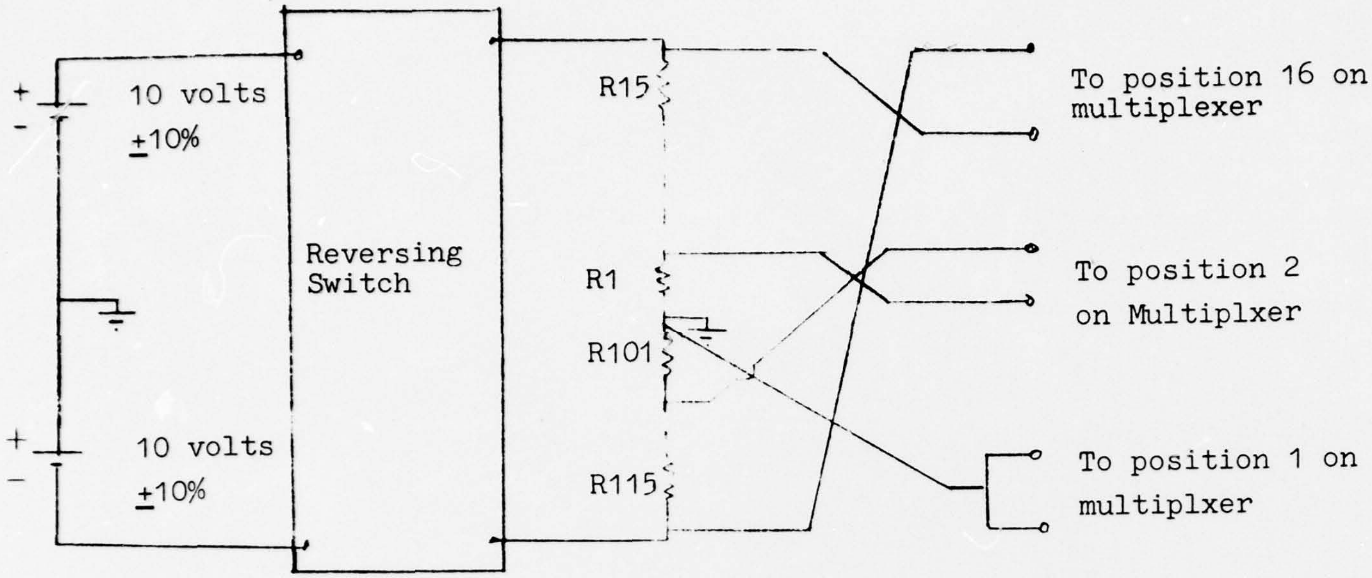
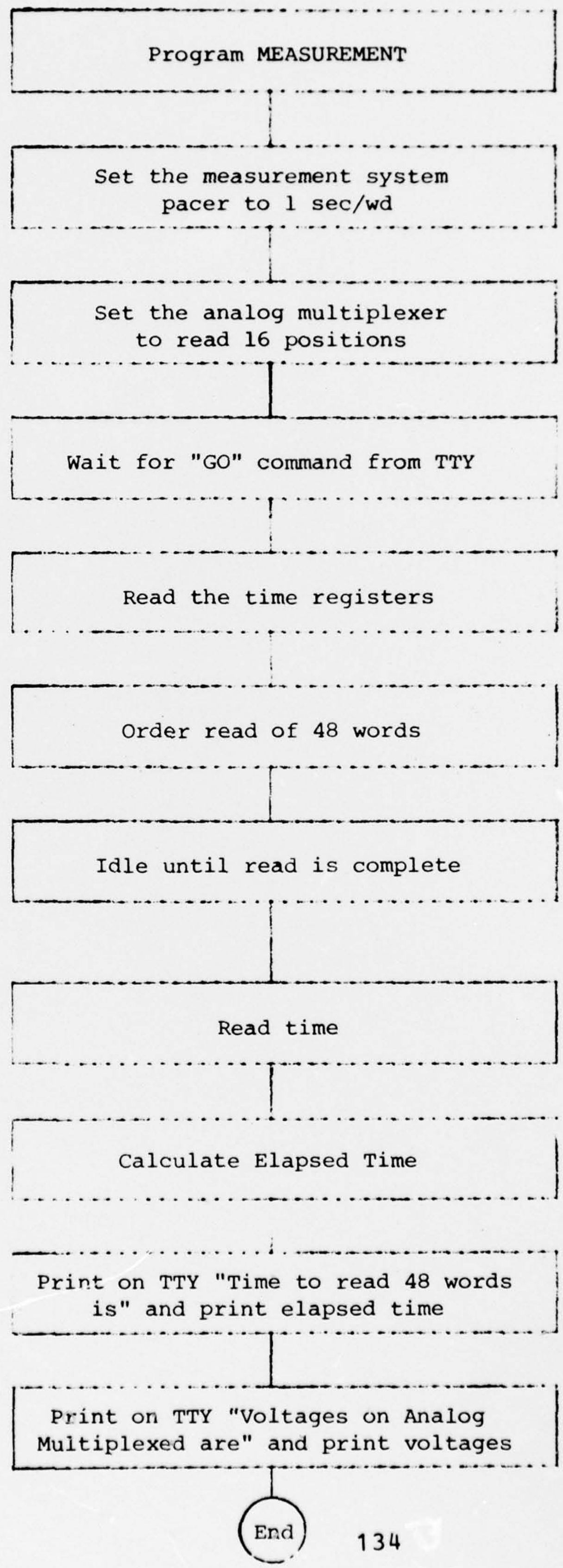


Figure 3.3.-1
Divider Input

FIGURE 3.3-2

PROGRAM MEASUREMENT



3.4 Interface System

The Hewlett-Packard supplied portion of the interface subsystem is shown in Figure 2-2. It is the portion of the system which is multiplexed through the 6940A digital controller. Connect all hand shake lines to each other.

3.4.1 Digital Input Test

Apply voltages corresponding to alternate zeros and ones to digital input 1. Run the program "DIGITAL INPUT" whose functional flow chart is given in Figure 3.4-1. Apply a "GO" signal to the TTY. Observe that the TTY printout corresponds to the input voltage pattern.

Repeat the above for alternate ones and zeros.

Modify the program to read digital input 2 and repeat the above.

3.4.2 Digital Output Tests

Run the program "DIGITAL OUTPUT" whose functional flow chart is shown in Figure 3.4-2. Measure each bit voltage on digital outputs 1 and 2 to check that they are alternate zeros and ones.

Repeat for alternate ones and zeros.

3.4.3 Relay Tests

Run the program "RELAY CLOSURE" whose functional flow chart is shown in Figure 3.4-3. Check with multimeter that all contacts are open. Enter "GO" command on TTY. After TTY prints out that contacts are closed, check them with a multimeter.

3.4.4 Event Sense Tests

Run the program "EVENT SENSE", whose functional flow chart is shown in Figure 3.4-4. Apply voltage corresponding to a logic 1 on bit 1 of input to event sense. All other bits shall be zero. Enter "GO" on TTY. Observe that the TTY printout indicates a 1 on bit 1. Repeat for the remaining eleven bits of the event sense.

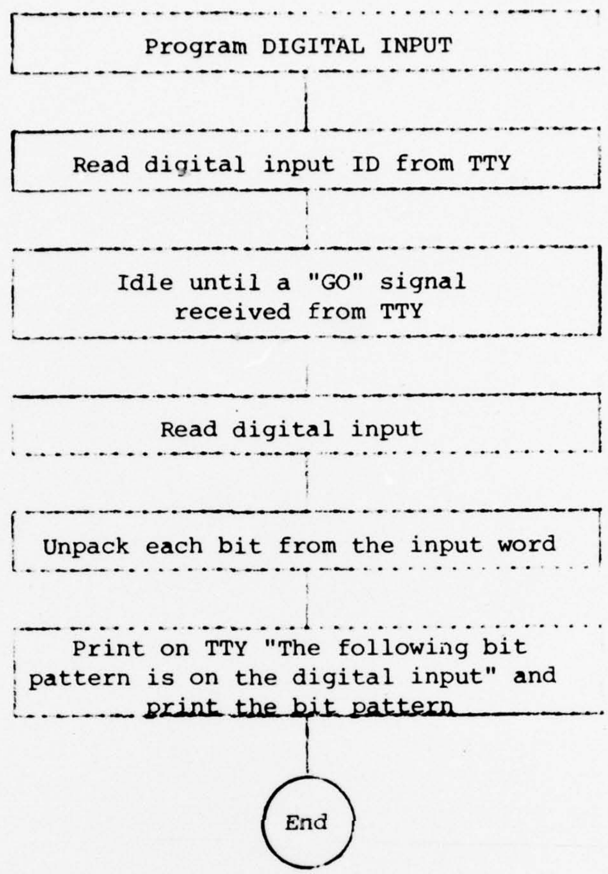


FIGURE 3.4-1

PROGRAM DIGITAL OUTPUT

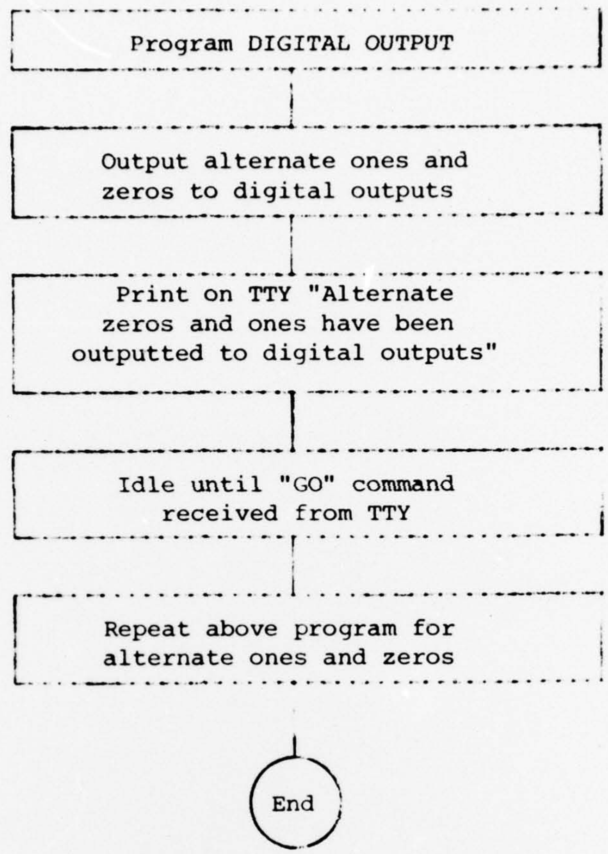


FIGURE 3.4-2

PROGRAM DIGITAL OUTPUT

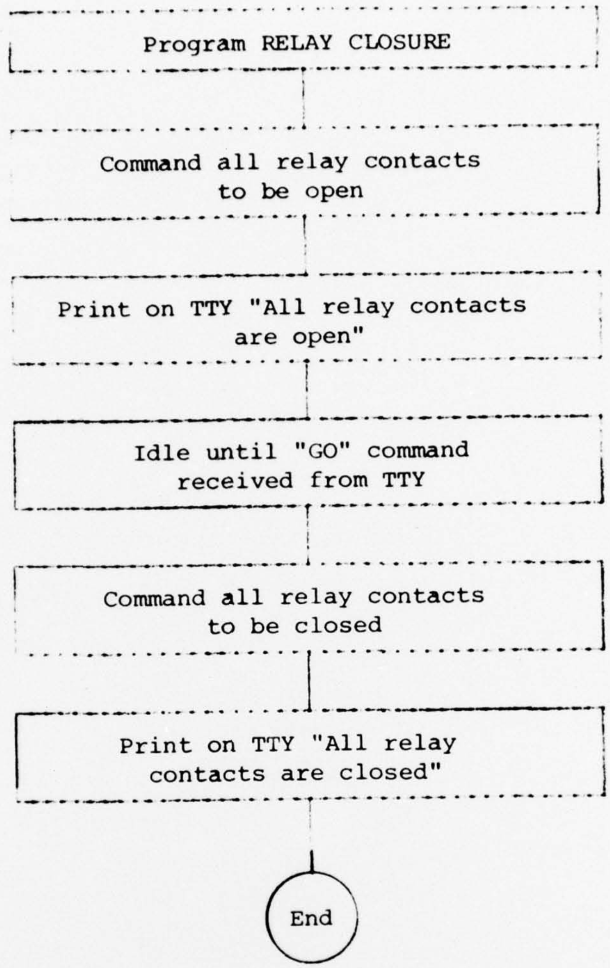


FIGURE 3.4-3

PROGRAM RELAY CLOSURES

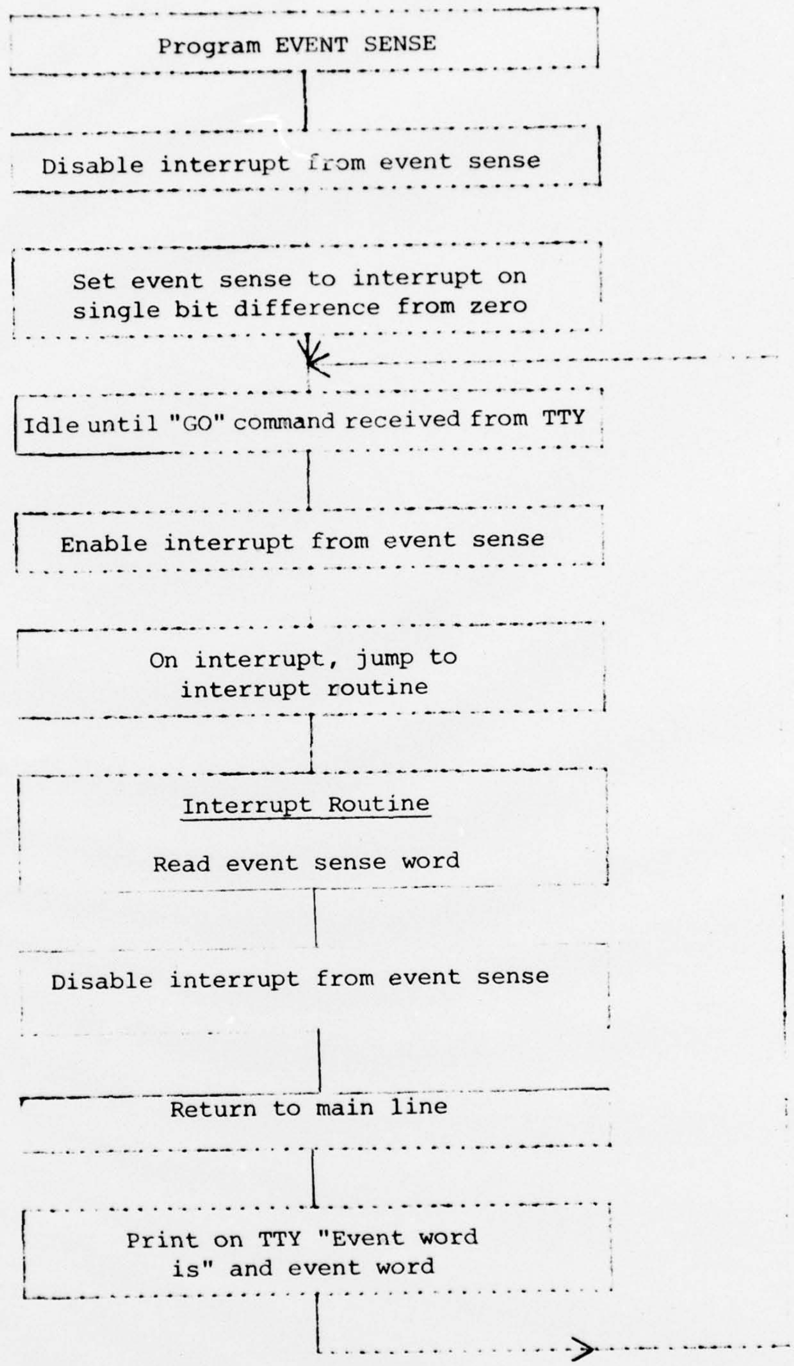


FIGURE 3.4-4

PROGRAM EVENT SENSE

3.5 Laser Trimmer Subsystem Integration Tests

CAUTION: Safety glasses must be worn during all laser trimmer tests. All persons not wearing safety glasses must be excluded from the room containing the equipment.

Three sets of tests will be performed. The first is the laser status check, the second is the position indication, and the third is the laser commands test. Use the 2 inch lens for all tests.

Laser Status

The laser status word is as follows:

Bit 1	acknowledge
Bit 2	laser enabled
Bit 3	X ready
Bit 4	Y ready
Bit 5	Manual mode
Bit 6	Not (X minus) limit switch
Bit 7	Not (X plus) limit switch
Bit 8	Not (Y minus) limit switch
Bit 9	Not (Y plus) limit switch
Bit 10	Power on
Bit 11	Water flow OK
Bit 12	Water temperature OK
Bit 13	Water resistivity OK
Bit 14	All interlocks closed
Bit 15	Q-switch RF drive OK
Bit 16	Q-switch temperature OK
Bit 17	Laser power OK
Bit 18	Pump beam current OK

Run program "Laser Status" whose functional flow chart is given in Figure 3.5-1. Turn laser on and put it into the manual mode.

Check the LED indicator at each status word bit to verify that all are in the normal condition. Type "GO" at the TTY. The program will read the laser status word (word 1) and print the contents on a bit by bit basis. Verify that all zeros have been printed.

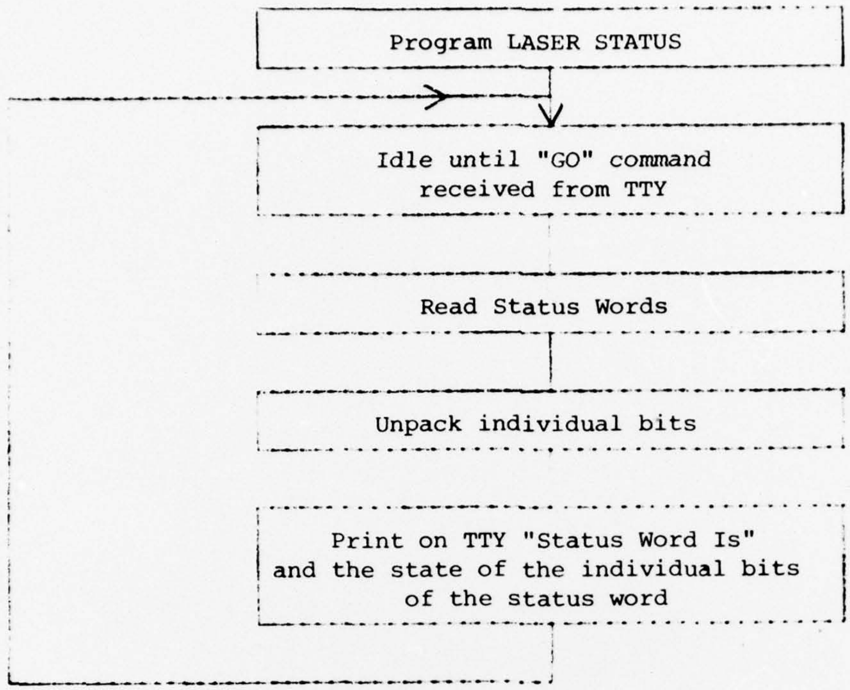


FIGURE 3.5-1

PROGRAM LASER STATUS

Introduce a fault at each bit in succession. Temperature faults must be simulated to avoid stress to the laser. After the fault is applied, the corresponding LED should light up. Enter "GO" at the TTY. The status word will be read by the computer and printed out. Verify that it corresponds to the LED pattern. After all bits have been checked and it is verified that the data is read correctly by the computer, restore the laser subsystem to its normal condition.

Laser Position Indication

Run Program "Laser Position Indication" whose functional flow chart is given in Figure 3.5-2. Using the joystick, manually set the laser beam to the (o,o) position. Enter "GO" at the TTY. The computer will read and print out the X and Y positions. Verify that they correspond to the position which was manually entered.

Repeat for the following positions:

X = 0.5"	Y = 0.5"
X = 1.0"	Y = 1.0"
X = 1.5"	Y = 1.5"
X = 2.0"	Y = 2.0"

Laser Command Sequence

Commands are sent to the laser over a single set of lines. The ID of command word is designated by a 2-bit code appearing on bits 15 and 14.

No data equals	set bit 15 to 1; bit 14 to 1
An X command equals	bit 15 to 1; bit 14 to 0
A Y command equals	bit 15 to 0; bit 14 to 1
A control command equals	bit 15 to 0; bit 14 to 0
Word 1	12-bit binary X position, bits 1-12
Word 2	12-bit binary Y position, same convention as Word 1
Word 3	Bit 1 - Laser enable equals logic "1"
	Bit 2 - Laser inhibit equals logic "1"
	Bit 3 - Execute equals logic "1"
	Bit 4 - Trim equals logic "1"
	Bit 5 - Home equals logic "1"
	Bit 6 - Trim complete equals logic "1"

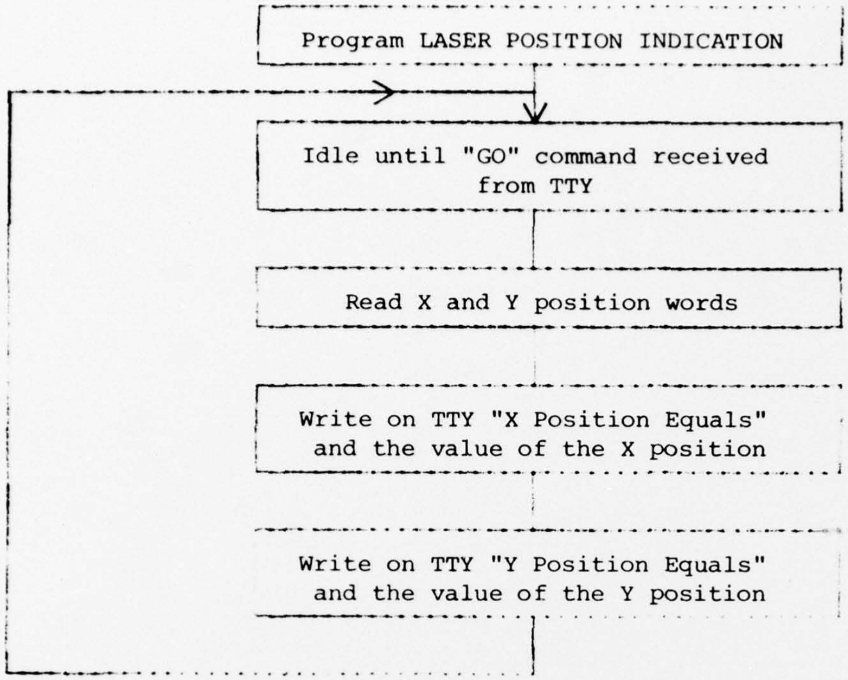


FIGURE 3.5-2

PROGRAM LASER POSITION INDICATION

Enter the following laser parameters:

Lamp Current	18 Amp
Iris	225
Spot	3
Overlap	Medium (50 percent)
Repetition Rate	5KHz
Trim Speed	0.5 inches/sec.
Slew Speed	4 inches/sec.

Put the laser trimmer into the computer control mode. Position a fuze amplifier thick film resistor on the laser table in the (o,o) position. Run the Program "LASER COMMANDS" whose functional flow chart is shown in Figure 3.5-3.

Enter "GO" at the teletype. The computer will print out the first command which it will issue to the trimmer. After the printing is complete, the computer will idle for ten seconds and then actually issue the command. Verify that the command has been executed. If it is desired that the command be repeated, enter "REPEAT" at the TTY. Otherwise, enter "CONTINUE" and the next command will be printed and executed.

Verify that it too has been correctly executed. After all the tests have been completed, the TTY will print "End of Laser Command Tests". If it is desired to re-run the command tests, the program must be started again.

The following command sequence will be issued:

Laser Off:Slew to:

Position	(0,0)
Position	(0.5", 0.5")
Position	(1.5", 1.5")
Position	(2.0", 2.0")

Home (to (0,0))

Trim Resistor from (0,0) to (0.05", 0)

3.6 Modulator Integration Tests

The modulator will provide the RF signals required to test the fuze oscillator. The cabinet will also contain the switching and control circuits needed to test and trim the unit. At the present, these circuits have not been finalized. After this is done, this section will be

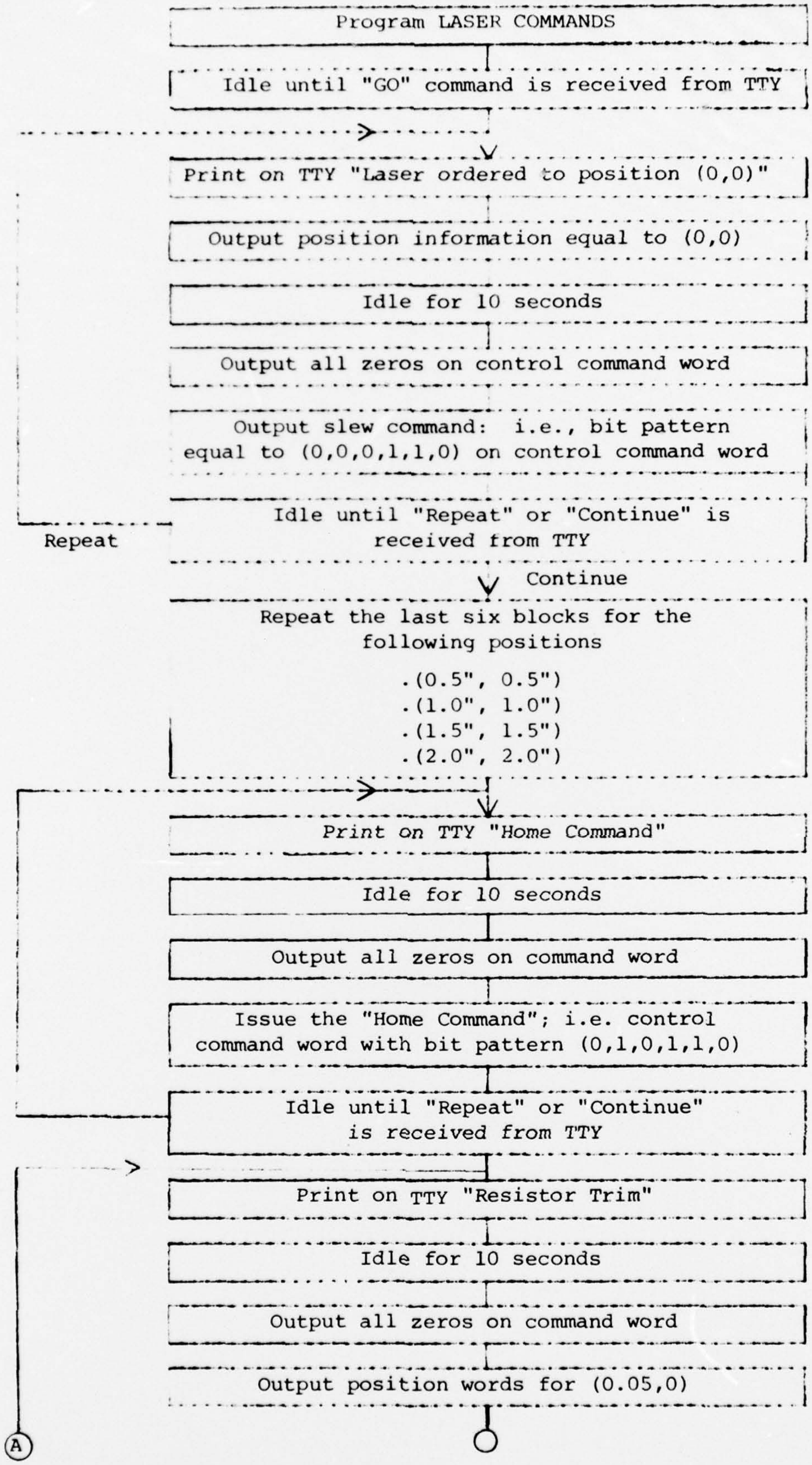


FIGURE 3.5-3

PROGRAM LASER COMMANDS

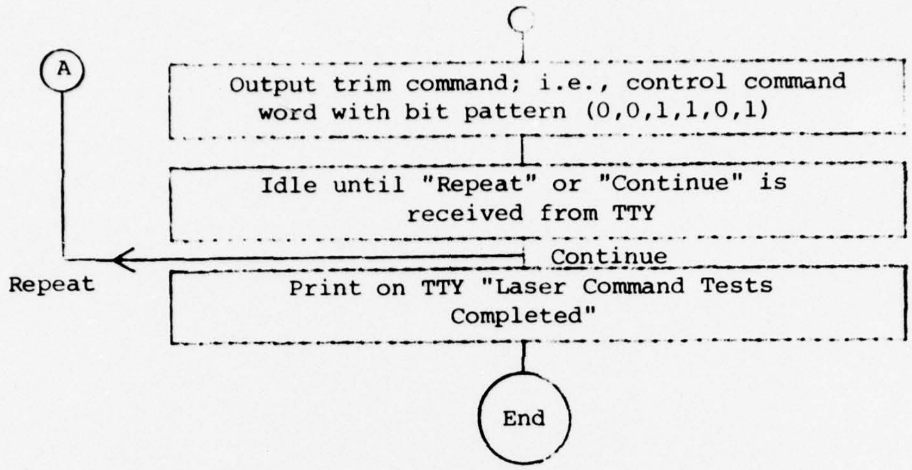


FIGURE 3.5-3

(cont'd)

PROGRAM LASER COMMANDS

expanded to include integration tests with the modulator. The following modulator subsystem functions and capabilities will be tested:

- Response to single sideband modulation
- Response to amplitude modulation
- Suppression of unwanted sidebands
- Loop gain
- Switching and interface

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During the fourth quarter, the major components of the test station were delivered to LEC. These components consisted of the following subsystems: Computer control, Stimulus, Measurement, Interface, and Laser Trimmer. The first four subsystems were re-integrated and checked as a total system by LEC.

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